REVIEW AND UPDATE OF BIO - ECONOMIC MODELS OF ACID DEPOSITION

Prepared by:

The DPA Group Inc. in association with
Corexco Ltd.

For:

Policy and Planning Branch
Ontario Ministry of the Environment

July 1987

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FINAL REPORT

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ABSTRACT

In 1980-81, the Ontario Ministry of the Environment (MOE) commissioned the development of a set of computer models to estimate biophysical consequences of acid deposition and their economic implications. These models are reviewed and updated to reflect more currently available data and new research findings. The review and update focuses on three receptor categories:

- forestry;
- agriculture; and
- human systems.

In addition, the deposition components of these models are reviewed and the model's structure evaluated.

For each sector model, both the biophysical and the economic valuation components are examined. Recommendations for revisions cover methodology, data, and model parameters.

Scientific information on the biophysical effects of acid deposition is still incomplete. In many cases dose-response relationships are still not available. The recommendations contained in this report, therefore, should be viewed as part of an on-going process to continually monitor available information and, when appropriate, incorporate it into the MOE models.

The review suggests that the basic structure of the 1980 models be maintained, but that the specifics for each sector be revised. Major recommendations include:

1. Modify calculation of deposition levels to (i) eliminate the separation of natural and anthropogenic deposition and (ii) tailor estimates of deposition to each sector and each type of effect. For example, above-ground effects in forestry and agriculture should be based on wet deposition levels during the active growing season.

2. Change parameters of the above ground dose-response relationship for forestry so that acid deposition of (average) pH 3.5 has no effect.

3. Eliminate crop-specific dose-response relationships in the agricultural model in favour of a single stochastic relationship for all crop types.

4. Maintain the material category approach to estimating the effects on materials; however, MOE should monitor and, to the extent possible, contribute to efforts to develop a data base of structures at risk.

5. Include steel as a material at risk and revise the corrosion formula for zinc.

6. Transfer the model to a micro-computer and combine it with a geographic information system to facilitate input, manipulation and display of spatial data. If the model is intended for active use by several parties for policy and research planning, then the code should, eventually, be rewritten.

Implementation of this report's recommendations should encourage greater use of the models and provide up-to-date estimates of the economic effects of acid deposition.

RÉSUMÉ

En 1980-1981, le ministère de l'Environnement de l'Ontario a demandé la conception d'un ensemble de modèles informatiques permettant d'évaluer les conséquences biophysiques des dépôts acides et leurs impacts économiques. Ces modèles font l'objet d'un examen et d'une mise à jour afin de tenir compte des nouvelles données et découvertes scientifiques. L'examen et la mise à jour mettent l'accent sur les secteurs de retombées suivants :

- la sylviculture;
- l'agriculture; et
- les systèmes humains.

De plus, les composantes de ces modèles traitant des dépôts acides font l'objet d'un examen, et la structure du modèle, d'une évaluation.

Pour chaque modèle de secteur, les composantes d'évaluation biophysique et économique sont étudiées. Les révisions recommandées touchent la méthodologie, les données et les paramètres du modèle.

Les renseignements scientifiques sur les effets biophysiques des dépôts acides sont incomplets. Dans plusieurs cas, aucune donnée sur les rapports dose-réaction n'est disponible. C'est pourquoi, les recommandations de ce rapport doivent être considérées comme faisant partie d'un processus continu visant à recueillir les données disponibles et, dans certains cas, à les incorporer aux modèles du ministère.

À la suite de l'examen, on recommande que la structure de base des modèles de 1980 soit conservée mais que les éléments spécifiques de chaque secteur soient réétudiés. On recommande :

1. De modifier le calcul des concentrations de dépôts afin i) d'éliminer la séparation des dépôts naturels et anthropogéniques et ii) d'adapter les évaluations de dépôts à chaque secteur et aux différents effets. Par exemple, en sylviculture et en agriculture, les effets au dessus du sol devraient être basés sur les concentrations des précipitations au cours de la saison de croissance.

2. De changer les paramètres du rapport dose-réaction au dessus du sol utilisés en sylviculture afin qu'un dépôt acide d'un pH moyen de 3,5 n'ait aucun effet.

3. D'éliminer du modèle utilisé en agriculture les rapports dose-réaction spécifiques à certaines récoltes pour les remplacer par un seul rapport stochastique utilisé pour tous les types de récoltes.

4. De conserver la catégorisation par matériau utilisée pour évaluer les effets sur les matériaux; toutefois, le ministère devrait suivre les efforts visant à élaborer une banque de données sur les structures menacées et y contribuer dans la mesure du possible.

5. **D'inclure l'acier dans la liste des matériaux menacés et de réétudier la formule de corrosion du zinc.**

6. De transférer le modèle à un micro-ordinateur et de l'associer à un système d'information géographique afin de faciliter l'entrée, le traitement et la présentation des données spatiales. Si le modèle est utilisé par plusieurs personnes pour la planification de politiques et de recherches, le code devrait être éventuellement récrit.

L'application des recommandations de ce rapport devrait favoriser une plus grande utilisation des modèles et devrait fournir des estimations à jour de l'impact économique des dépôts acides.

REVIEW AND UPDATE OF MOE'S ECONOMIC MODELS OF ACID DEPOSITION

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EXECUTIVE SUMMARY

In 1980-81, the Ontario Ministry of the Environment (MOE) commissioned the development of a set of computer models to estimate biophysical consequences of acid deposition and their economic implications. These models were reviewed and recommendations made to reflect more currently available data and new research findings. The review and update focused on three receptor categories:

- forestry;
- agriculture; and
- human systems.

In addition, the deposition components of these models are reviewed and the model's structure evaluated. For each sector model, both the biophysical and the economic valuation components are examined. Recommendations for revisions cover methodology, data, and model parameters.

Scientific information on the biophysical effects of acid deposition is still incomplete. In many cases, dose-response relationships are still not available. The following recommendations, therefore, should be viewed as part of an on-going process to continually monitor available information and, when appropriate, incorporate it into the MOE models.

The review suggests that the basic structure of the models be maintained, although changes to specifics of each sector model are recommended. The major recommendations are discussed below.

Deposition Components

In the deposition components of the models, it is suggested that the separation of natural and anthropogenic deposition be eliminated. Since we are only interested in the changes in costs and benefits associated with changes from current acid deposition levels, the natural component of deposition is not needed. Furthermore, "natural" levels vary considerably from region to region and are very uncertain. The revised model should also allow the user to adjust the mix of ions in the deposition to capture the effects of emission controls (e.g., different control regulations for sulfur and nitrogen emissions).

It is also suggested that deposition levels which are used in dose-response relationships be tailored to each sector and to each type of effect. For example, above ground effects in forestry and agriculture should be based on wet deposition levels during the active growing season (i.e., May to October); for soil effects, total annual deposition should be calculated but prorated by some user-specified parameter to indicate the amount of deposition which remains in the soil; estimates of dry deposition should be added to wet deposition in calculating soil impacts for forestry and agriculture and for calculating impacts on human systems.

Forestry Model

The basic structure of the forestry model should be maintained, however, the parameters for the above ground response function should be adjusted so that acid deposition of (average) pH 3.5 has no effect. In the soil component of the model, parameters relating base saturation and aluminum on tree growth were not available.

Changes to the economic valuation component of the forestry model focus on incorporating current management principles by basing harvest levels on Maximum Allowable Depletion concept rather than the now-outdated Annual Allowable Cut principle.

The economic effects of acid deposition are measured in the model by changes in wood harvesting costs. It is recommended that the relationship between potential yield (rather than tree size) and wood costs be further analyzed, possibly drawing on output from the FORCYTE model or from a survey of private operators in Ontario's wood industries.

Agriculture Model

There has been considerably more scientific work done on the effects of acid deposition on agricultural crops than on forest resources. Revisions to the 1980 agriculture model are suggested for above ground and soil impacts, as well as economic valuation. For above ground effects, updated information does not support crop-specific dose-response relationships. Instead, it is recommended that a single stochastic dose-response relationship for all crop types be used. The parameters for this relationship should be based on a published review of previously estimated functions.

In the soil component, the assumption that farmers will adjust their soil management practices to maintain the same soil chemistry is kept. Within the soil management component, suggested revisions relate primarily to the modelling of sulfate fertilizer amendments. The 1980 model calculates the amount of sulfur fertilizer additions replaced by deposition on an ion by ion basis. However, only 10-30 kg/ha is required on most Ontario agricultural soils, so that only sulfate deposition up to this level should be included as a substitute for applied fertilizer. Sulfate deposition above this level should be considered as neither a benefit nor a cost.

There are two major revisions recommended for the economic valuation of agricultural impacts. First, changes in economic value arising from price effects should be captured. These effects should be activated by the user by specifying a price elasticity, with a default setting price effects equal to zero. Second, forecasts of agricultural production should be based on the same set of macroeconomic assumptions as forestry. A common and consistent set of assumptions may be drawn from CANDIDE or RIM macroeconomic models. A similar recommendation holds for the economic component of the forestry model.

Human Systems Model

The human systems model consists of three parts:
- materials;
- water supply systems; and
- historic buildings and structures.

The necessary ingredients for a defensible model of the effects of acid deposition on materials suggests that a component approach be followed. The component approach considers damage to specific structures. The 1980 model is based on a material category approach which estimates impacts by type of material regardless of use. Unfortunately, the data base required for the component approach has not been developed, so the material category approach must be used. It is, however, recommended that MOE monitor and, to the extent possible, contribute to efforts to develop an appropriate data base of materials at risk. In the interim, two major changes should be made to material dose-response relationships. First, the effects of acid deposition on steel should be included. Second, the corrosion formula for zinc should be revised.

Economic valuation of the effects on materials depends on estimates of economic life and exposure factors for individual materials. In general, the MOE model uses estimates from a 1970 U.S. study. It is suggested that, until these factors are derived specifically for Ontario, they be verified by industry experts.

The economic implications of acid deposition for water supply systems should be calculated as the incremental chemical cost of raising the pH of intake water to its original (without acid deposition) level. To include a water supply treatment component in the model, considerable data must be collected on water flows, chemical costs, and the pH of intake water at individual treatment plants.

One of the requisites for identifying the effects of acid deposition on historic buildings and structures is an inventory of structures at risk. Unfortunately, no comprehensive inventory currently exists that has information on the number, location or type of material of historic structures. This report does, however, contain two partial lists from Public Works Canada and Environment Canada. MOE should monitor efforts to expand and refine this inventory.

The economic value of the effect of acid deposition on historic buildings and structures can be estimated by asking individuals what they would be willing to pay to avoid damage or, more practically, the cost of repairing the damage. No studies specific to acid deposition or to Ontario have been completed to date. Some case studies should be undertaken, but written up separately from the results of the MOE computer models.

Model Structure

The Interactive Financial Planning System (IFPS) software is is a good environment for model development. However, the 1980 models are difficult to use; there are no interactive modules to prompt the user; and it is difficult to make changes to the data, model parameters or the program code itself. Problems related to model maintenance, data management capabilities and cost effectiveness were also identified. One of the consequences of these problems is that the model is not used extensively.

It is recommended that the models be transferred to a microcomputer version of IFPS and that they be used in conjunction with a geographic information system for both data input and display of results. If the models are intended for active use by several people for policy and research planning, then the code should, eventually, be rewritten to make it more user friendly and to facilitate sensitivity testing and model maintenance.

Implementation of this report's recommendations should encourage greater use of the models and provide up-to-date estimates of the economic effects of acid deposition.

1.0 INTRODUCTION

Acid deposition, its environmental and socioeconomic consequences, and its control have rapidly become major issues facing Canadian society. These issues have raised concerns and questions about appropriate policy both within Canada and internationally - especially in bilateral discussions with the United States. As the issues move into the public policy arena, it is critical that decision-makers have information suited to their needs.

In 1980-81, the Ontario Ministry of the Environment (MOE) commissioned the development of a set of computer models (henceforth referred to as the 1980 models) which may be used to estimate certain biophysical consequences of acid deposition and their economic implications. These models addressed the following receptor categories:

- agriculture
- forestry
- commercial furs
- commercial fisheries
- selected structural materials (human systems).

The models are described in the report: "A Methodology for Estimating the Impacts of Acid Deposition in Ontario and their Economic Value" by Victor and Burrell (1982).

Biological and physical relationships and acid deposition dose-responses which were incorporated into these models were based on available information and literature up to 1980. Similarly, inventory data was based on 1980 (or earlier) statistics.

In the past five years, since the 1980 models were developed, there has been considerable research and information generated on the effects and consequences of acid deposition. In December, 1985 the Ontario Ministry of Environment (MOE) commissioned the DPA Group (in association with Corexco Ltd.) to review and update these models to reflect more currently available data and new research findings. The review and update focuses on three of the receptor categories:

- agriculture;
- forestry; and
- human systems.

This report presents the findings and recommendations of the review. The report is structured as follows:

- Section 2 outlines the treatment of deposition in the 1980 model and recommendations for revision.
- Sections 3 through 5 cover the forestry, agriculture, and human systems models, respectively. For each sector, the 1980 model is described, recommended revisions documented, the Victor and Burrell (1982) recommendations reviewed, and data requirements and availability noted.
- Section 6 covers possible computer environments for the models. The discussion begins with an audit of the structure and performance of the 1980 model and concludes with recommended revisions to the program code to incorporate new dose-response relationships or economic valuation methods. Data management options are also reviewed.
- Section 7 summarizes the study's recommendations.

The remainder of the introduction provides background on the 1980 models and a brief overview of the work program undertaken in the review and update of the models.

1.1 Overview of the 1980 Models

The 1980 models were developed as one of three studies funded by MOE on the socioeconomic effects of acid deposition. One study addressed amenity and aesthetic values affected by acid deposition and a second considered its implications for tourism and outdoor recreation.

The third study - on which this report is based - addressed the "impact on biological systems and human artifacts for which there are explicit market values" (Victor and Burrell, 1982) The original objectives of the study were to develop quantitative estimates of the effects of acid deposition on goods and services for which market prices were available and to estimate the economic value of those effects.

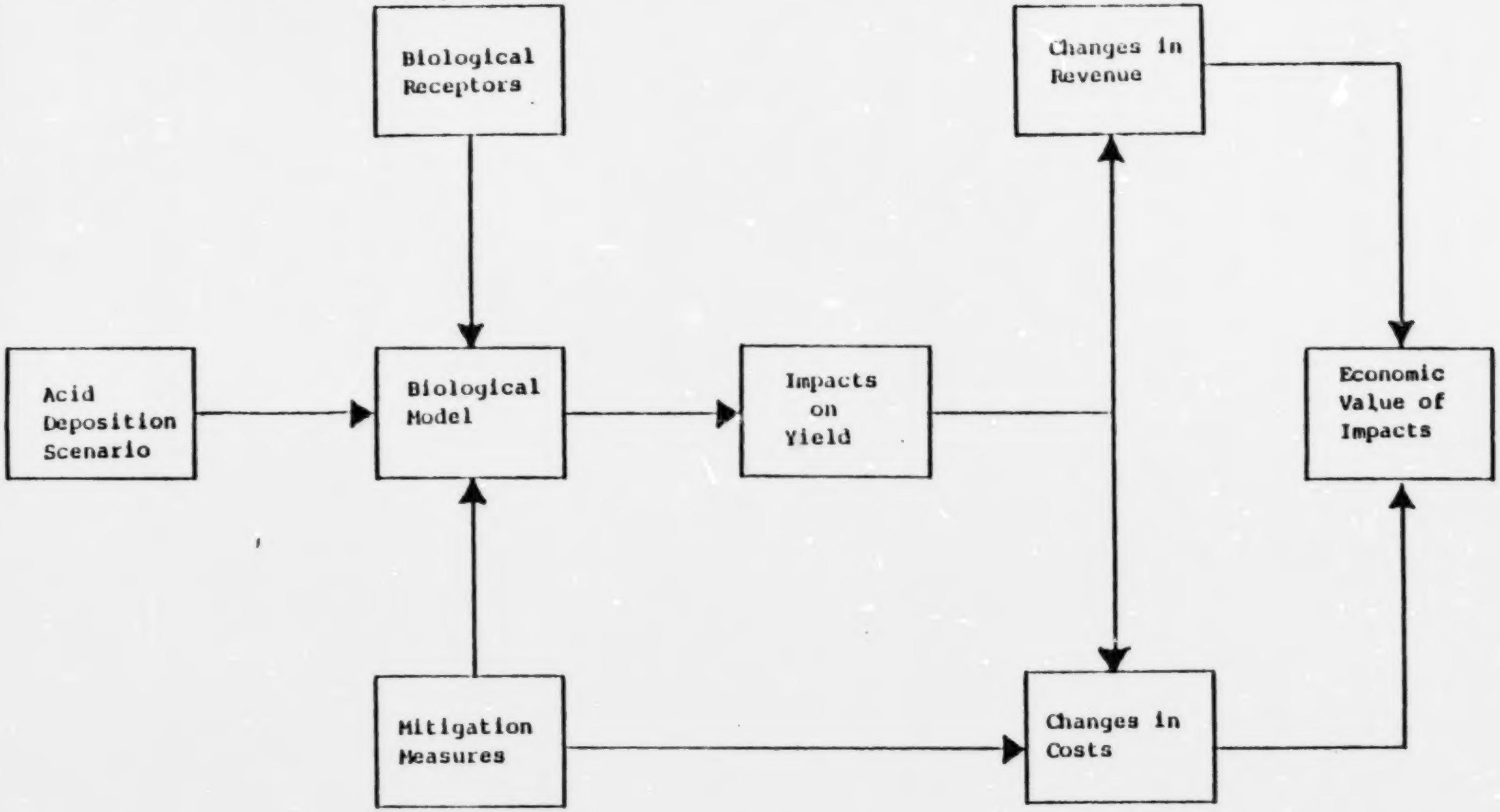
However, the consultants were faced with a relative void of useful information on biophysical responses to acid deposition. The focus of the study, therefore, was changed to be "the development of a preliminary, yet comprehensive, methodology for generating estimates of acid deposition impacts in Ontario and their economic value" (Victor & Burrell, 1982). Less emphasis was placed on generating quantitative economic values for acid deposition impacts.

The resulting methodology consists of five separate models, one for each of the major receptor categories, as noted above. There are two interrelated components within each receptor model. The first component models biophysical responses of resources to acid deposition; the second translates physical units of impact into monetary values. Exhibits 1.1 and 1.2 show the major elements for the biological systems models (e.g., forestry, agriculture), and for building and materials, respectively.

Each sectoral model is described in more detail in Sections 2.1, 3.2, 4.2, and 5.2 below.

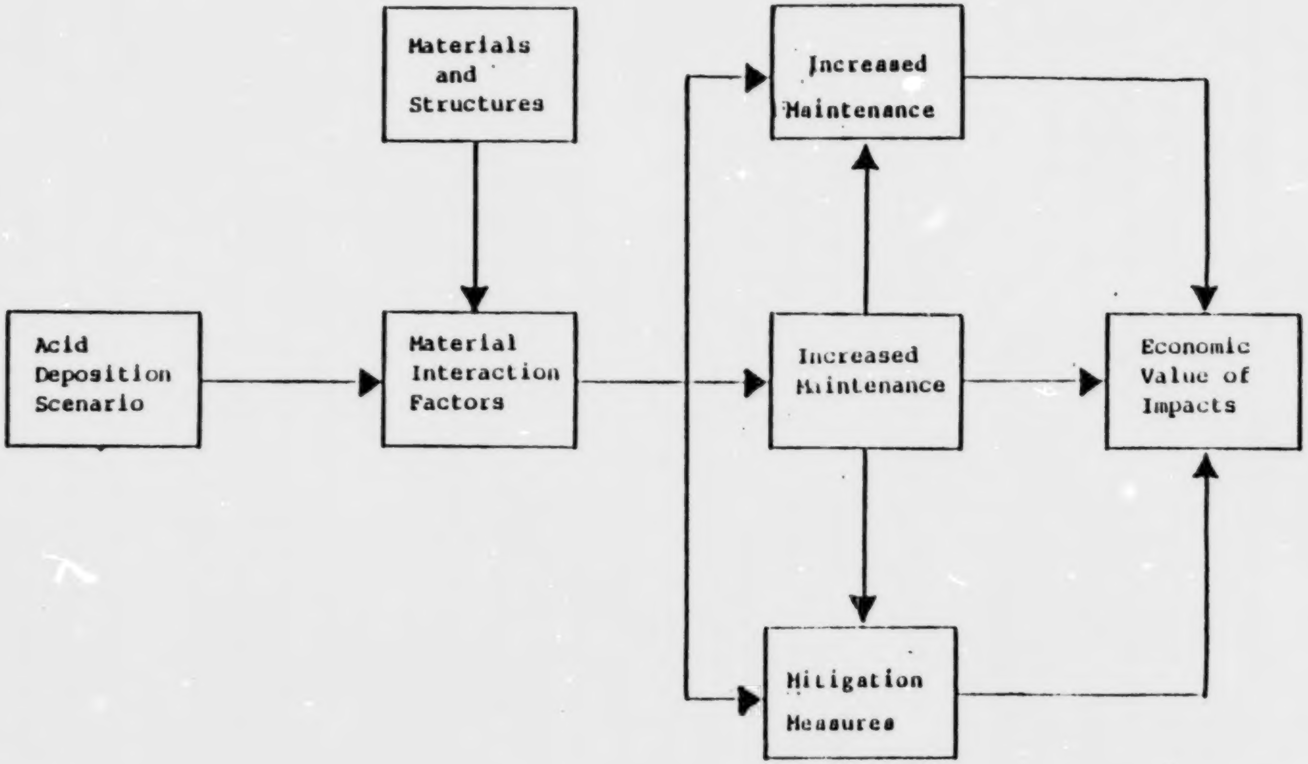
The 1980 models analyze potential impacts of acid deposition over a 22 year period. Although final results are available on province-wide aggregate basis, the estimates are derived

EXHIBIT 1.1: Victor & Burrell Analytical Framework: Biological Systems


Biological Receptors
Changes in Revenue
Acid Deposition Scenario
Biological Model
Impacts on Yield
Economic Value of Impacts
Mitigation Measures
Changes in Costs

Source: Victor and Burrell (1982).

EXHIBIT 1.2: Victor & Burrell Analytical Framework: Buildings & Materials


Materials and Structures
Acid Deposition Scenario
Material Interaction Factors
Increased Maintenance
Increased Maintenance
Mitigation Measures
Economic Value of Impacts

Source: Victor and Burrell (1982).

from separate calculations for 64 ecologically distinct subregions. The multi-regional approach allows for differences in acid deposition levels, resource inventories, and buffering capacity. All data necessary to run the models were calculated for each of the 64 regions and subsequently stored in the Ontario Government's Downsview computer, along with the models' programs.

The 1980 models incorporate a Monte Carlo procedure to explicitly take account of the considerable uncertainties in the postulated dose-response relationships. In the Monte Carlo procedure, various causal relationships are represented as probability functions so that estimates of acid deposition impacts and their economic values are presented with their associated variances.

1.2 Review Methodology and Work Program

The review and update of the 1980 models progressed in three phases. The first phase included a review of the existing models and assembly of updated research and information. As indicated in Exhibit 1.3, the first phase of the work program was composed of five main elements or tasks:

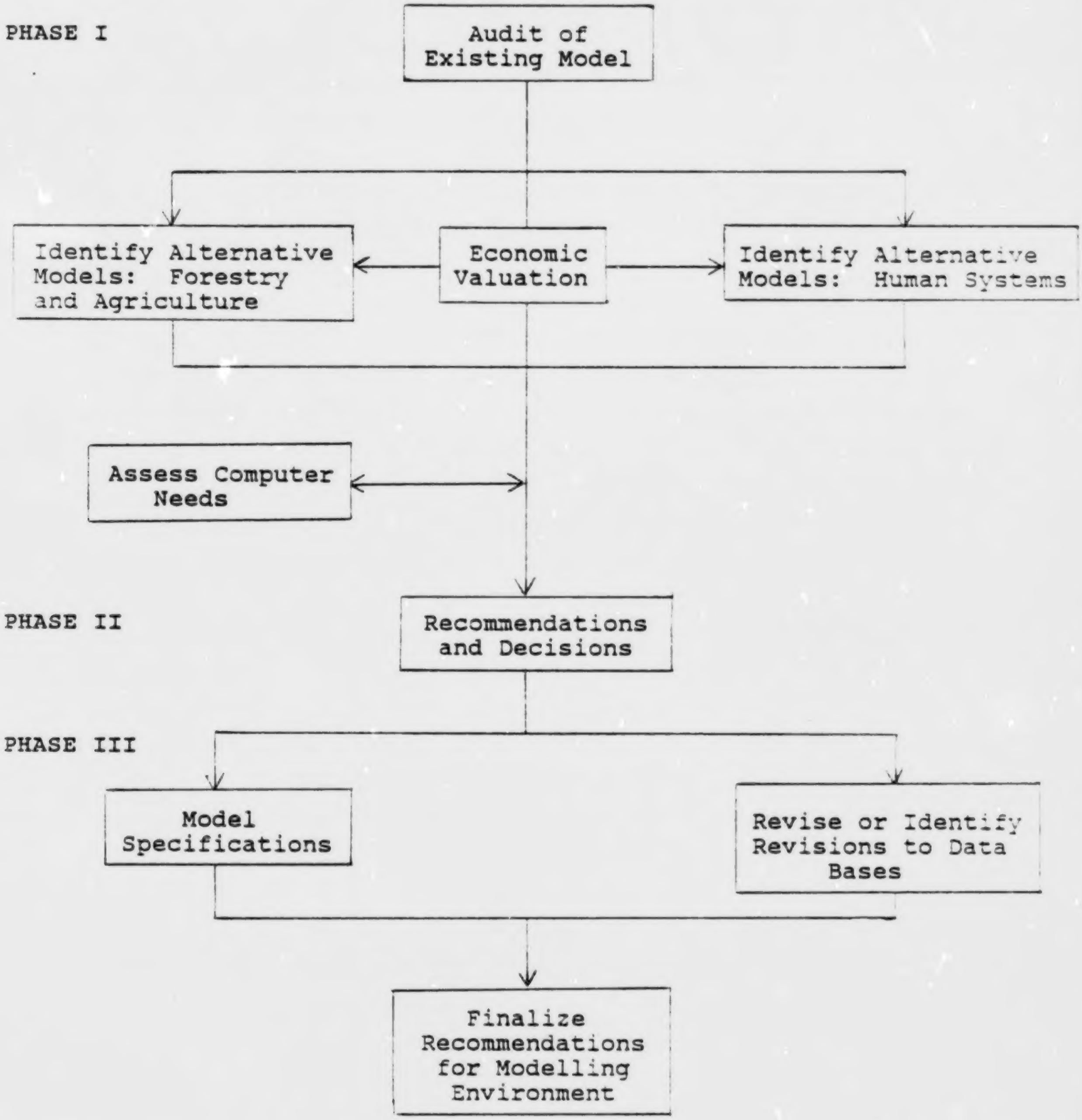
- audit of the existing model;
- identification of alternative models (forestry and agriculture);
- identification of alternative models (human systems);
- economic valuation assessment; and
- assessment of computer needs.

In Phase II, this information was synthesized and options and recommendations for model update developed. Recommendations focus on immediate changes, but also include recommendations for further research.

The third phase of the work program commenced after recommendations had been reviewed and decisions taken by MOE. The third phase was composed of three major tasks:

- specification for model/programming revisions;

EXHIBIT 1.3: OVERVIEW OF WORK PROGRAM


PHASE I
Audit of Existing Model
Identify Alternative Models: Forestry and Agriculture
Economic Valuation
Identify Alternative Models: Human Systems
Assess Computer Needs
PHASE II
Recommendations and Decisions
PHASE III
Model Specifications
Revise or Identify Revisions to Data Bases
Finalize Recommendations for Modelling Environment

- revisions or identification of revisions to databases; and
- finalization of recommendations for modelling environment.

2.0 DEPOSITION MODEL

2.1 Description of the 1980 Model

The 1980 deposition model was briefly reviewed at the workshop on acid deposition impacts on forestry and agriculture held as part of this study (see Section 3.1) and at meetings with MOE representatives.

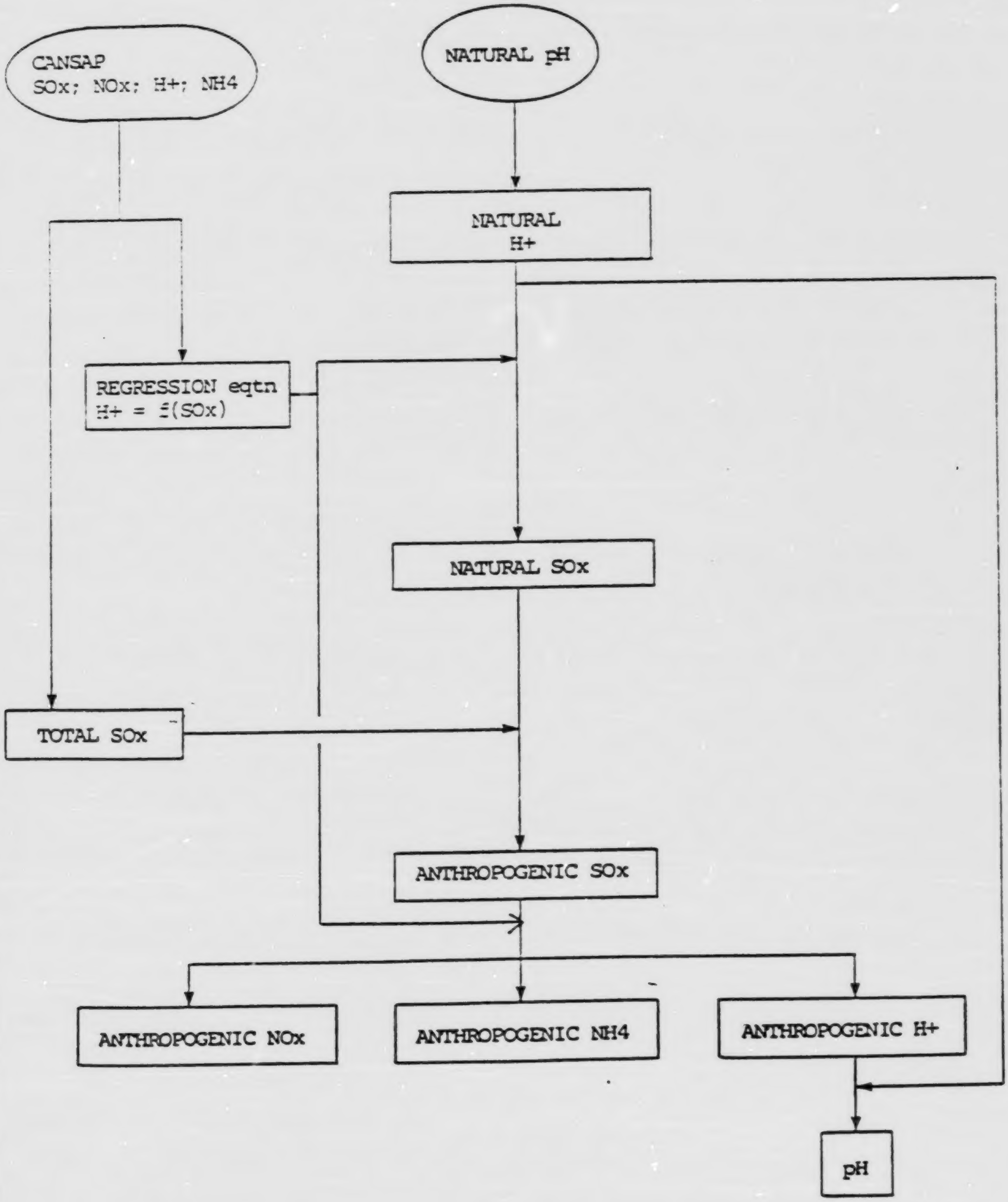
The 1980 model assumes that deposition of all materials is correlated with deposition of sulfate ions (see Exhibit 2.1). Data on the deposition rate of the four major ions (hydrogen, ammonia, nitrate and sulfate) were used to establish statistical relationships among them. These relationships together with an assumed background pH were used to partition deposition into "natural" and anthropogenic components. The natural component was assumed to be related to rain with a pH of 5.6. Given the hydrogen ion concentration and the statistical relationship between hydrogen and sulfate, the "natural" portion of the sulfate deposition was estimated.

All nitrogen compounds were aggregated together based on the proportion of atomic weight of nitrogen in the compounds. This was related (statistically) to sulfate and was partitioned into natural and anthropogenic sources accordingly. Throughout the 1980 model all calculations of impacts were partitioned into natural and anthropogenic levels based on these derived proportions.

Deposition scenarios were constructed by changing sulfate depositions; all other ions changed according to the overall statistical relationships.

Dry deposition was not included in the model.

EXHIBIT 2.1: 1980 DEPOSITION MODEL


CANSAP
SOx; NOx; H+; NH4
NATURAL pH
NATURAL H+
REGRESSION eqtn
H+ = f(SOx)
NATURAL SOx
TOTAL SOx
ANTHROPOGENIC SOx
ANTHROPOGENIC NOx
ANTHROPOGENIC NH4
ANTHROPOGENIC H+
pH

Source: DPA Group Inc.

2.2 Recommended Revisions to Deposition Model

The separation of natural and anthropogenic components of the deposition can be eliminated from the model. Since we are only interested in the changes in costs and benefits associated with changes from current deposition rates, the natural component of the deposition is not needed. Furthermore, as was discussed in the workshop, "natural" levels vary considerably from region to region and are very uncertain.

Recommendation 1: Eliminate the separation of natural and anthropogenic effects.

It is unrealistic to assume that the ionic composition of the deposition will remain constant if emission controls are introduced. For example, the level of controls on sulfur and nitrogen emissions may differ.

Recommendation 2: The new model should allow the user to adjust the mix of ions in the deposition. To do this, acid deposition data for each of the four ions (i.e., hydrogen, sulfate, nitrate, ammonia) should be input separately.

Deposition data to start the model and for use in dose-response equations should be calculated over time periods during which the impacts occur. The appropriate periods vary by sector and impact mechanism. Above-ground effects for both agriculture and forestry occur during the active growing season (May-October). The appropriate period for soil impacts is more controversial and depends on one's estimate of the amount of deposition deposited during snow thaw. Using annual figures may overestimate deposition, while growing season figures may underestimate. Coote et. al. (1986) suggest that 65% of annual deposition remains and enters the agricultural system; but the actual proportion is not known with great certainty.

Corrosion rates for materials are developed based on annual pollutant concentrations; therefore, annual deposition figures should be used in the human systems component.

Recommendation 3: For above-ground effects in forestry and agriculture, wet deposition levels should be calculated for the active growing season (defined as May to October). For soil effects, total annual deposition should be calculated, but prorated by some user-specified parameter. The default value for the parameter should be 65% (Coote et. al., 1986); that is, 65% of annual deposition remains in the soil. For human systems, deposition levels over the whole year should be calculated.

The 1980 model makes no distinction between deposition that affects above ground parts of the plants and deposition that affects the soil. To facilitate the investigation of episodic deposition events and differences between above ground and soil effects, separate above ground and soil deposition rates for hydrogen ions should be available in the new model.

Recommendation 4: There should be two deposition parameters for hydrogen ions. The two parameters relate to above ground and soil effects which can be differentiated by the user. A default in the computer program should equate the parameters.

Above ground effects of dry deposition in both agricultural and forest systems are not well understood and can be left for the time being. However, estimates of dry deposition levels do exist for some sites in Ontario and the effects of dry deposition on soils and materials should be considered in the revised model.

Recommendation 5: Dry deposition data should be added to wet deposition estimates in calculating soil impacts for forestry and agriculture and for calculating impacts on human systems.

The impacts of acid deposition on water supply systems are determined by changes in water pH.

Recommendation 6: Average annual water pH should be calculated for the water supply component using the same methodology as in the 1980 model; average growing season pH should be calculated for forestry and agriculture above ground effects.

Given the purpose and scope of the exercise, modelling efforts should focus on incorporating scientific evidence of the effects of a limited range of acid deposition.

Recommendation 7: The pH range for simulations should be limited to "realistic" average levels calculated over a given time period and variations of: $3.5<pH<5.5$.

2.3 Data Requirements and Availability

Data on monthly average wet deposition for four ions must be assembled by region to operate the revised deposition model. The four ions are:

- hydrogen (H+);
- sulfate (SOx);
- nitrate (NOx); and
- ammonia (NH4).

A comparable set of data on dry deposition is also required.

The deposition data requirements for each of the sectoral models are summarized in Exhibit 2.2. As indicated, monthly data on wet deposition, aggregated over the active growing season (May through October) are required to estimate above-ground effects for both forestry and agriculture. For soil impacts, monthly data on both wet and dry deposition is accumulated over the whole year, but then prorated by a user-specified percentage (default set at 65%).

EXHIBIT 2.2: DEPOSITION DATA REQUIREMENTS

Sector	Component	Wet Deposition ($meq/m^2/month$) SOx	NOx	NH4	H+	Dry Deposition ($meq/m^2/month$) SOx	NOx	NH4	H+	Period[a]
Forestry	above ground	X	X	X	note b					May thru Oct.
	soil	X	X	X	note b	X	X	X	X	Jan thru Dec (pro-rated)[c]
Agriculture	above ground	X	X	X	note b					May thru Oct.
	soil	X	X	X	note b	X	X	X	X	Jan thru Dec (pro-rated)[c]
Human Systems		X			X	X			X	Jan thru Dec

Notes

[a] Period over which monthly deposition levels are cummulated.

[b] Above-ground and soil H+ can be varied by the model user.

[c] Prorated based on a user-specified proportion (or by a default value of 65%).

Because of the format and availability of dose-response relationships for human systems, wet and dry deposition for SO_x and H^+ only are required. Deposition should be cumulated over the year. Average annual pH levels are required to estimate water supply system impacts.

All data are available from the Air Resources Branch of the Ontario Ministry of Environment.

3.0 FORESTRY MODEL

3.1 Review Methodology

The methodology to review the forestry model consisted of three tasks:

1. An audit of the 1980 model.
2. A workshop of scientific researchers.
3. A literature review.

The audit of the 1980 model involved an examination of the computer code, simulation runs and sensitivity tests to identify operational parameters and critical relationships in the model. Based on this audit, a logic flow diagram for the 1980 forestry model was developed and a set of revision issues identified.

The workshop brought together the best available expert opinion in the field of biophysical impacts of acid deposition on forest and agricultural resources. The objectives of the workshop were: to gather up-to-date (including pre-publication) material and information; to expose differences in opinion within the scientific community about biophysical impacts; and to discuss other available models of effects.

The workshop was held over two days. During the first day, the 1980 model was reviewed and alternative structures discussed. The second day was devoted to a more detailed review of model relationships, current research findings and data availability. Both days were spent in plenary session to take advantage of the "cross-pollination" of disciplines.

Experts from both Canada and the United States participated in the workshop, representing government, industry and research institutes. A complete list of participants is included as Appendix A.

The audit and workshop were supplemented by a review of the literature. References were gathered from a computer literature search and workshop participants. In addition, the project team's specialist advisors had both recently concluded extensive literature reviews on this subject. Published information provided much of the data for revisions to model parameters and dose-response relationships.

3.2 Description of the 1980 Model

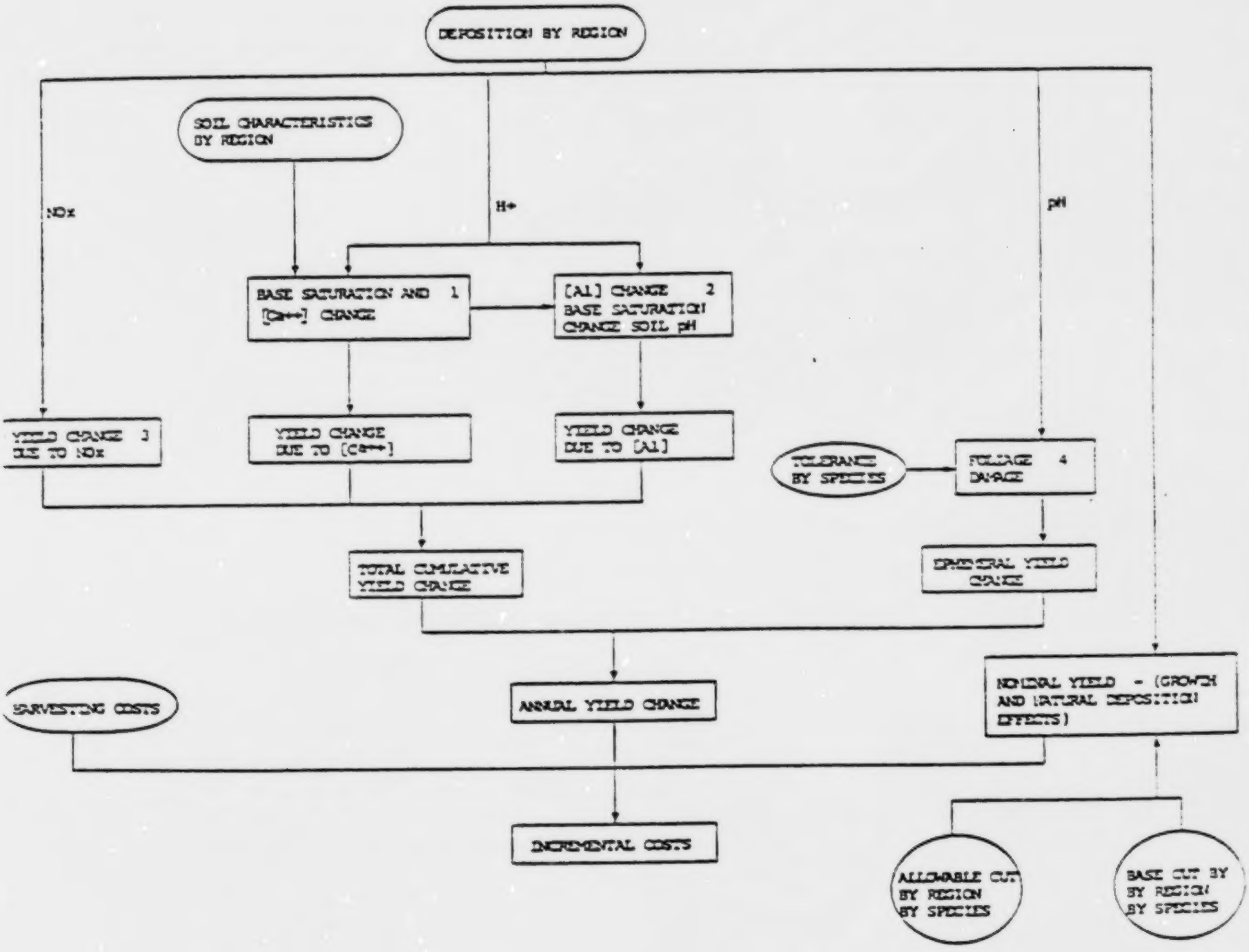
The 1980 forest model has three main components: foliar or above ground effects; soil mediated effects; and economic valuation. The main components and their interactions are illustrated in Exhibit 3.1.

3.2.1 Above Ground Effects

The 1980 model calculates direct effects of acid deposition on trees in two steps. The first relates changes in pH of precipitation to changes in photosynthetic capability. The model identifies three levels of sensitivity of photosynthetic capability to changes in pH. Twelve species groups are allocated to the three sensitivity classes. The sensitive class includes: jackpine, white birch, ash and elm. The intermediate class includes: maple, yellow birch, white and red pine and poplar. The tolerant class includes: spruce, cedar, fir and, oak. Exhibit 3.2 shows the assumed effect of pH on photosynthetic capacity for the three sensitivity groups.

The second step relates changes in photosynthetic capacity to changes in yield. This relationship was developed from data on the cotton plant (Brisley et al., 1959) and is illustrated in Exhibit 3.3. The change in yield due to foliar or above ground effects is assumed to be ephemeral (i.e., yields are affected only in the year deposition occurs, with no year-over-year impacts).

EXHIBIT 3.1: 1980 FORESTRY MODEL


DEPOSITION BY REGION
SOIL CHARACTERISTICS BY REGION
NOx
H+
pH
BASE SATURATION AND [Ca++] CHANGE 1
[Al] CHANGE BASE SATURATION CHANGE SOIL pH 2
YIELD CHANGE DUE TO NOx 3
YIELD CHANGE DUE TO [Ca++]
YIELD CHANGE DUE TO [Al]
TOLERANCE BY SPECIES
FOLIAGE DAMAGE 4
TOTAL CUMULATIVE YIELD CHANGE
EPHEMERAL YIELD CHANGE
HARVESTING COSTS
ANNUAL YIELD CHANGE
NOMINAL YIELD - (GROWTH AND NATURAL DEPOSITION EFFECTS)
INCREMENTAL COSTS
ALLOWABLE CUT BY REGION BY SPECIES
BASE CUT BY BY REGION BY SPECIES

Source: Victor and Burrell (1982).

EXHIBIT 3.2: FOLIAR DOSE - RESPONSE RELATIONSHIPS: FORESTRY (1980 Model)

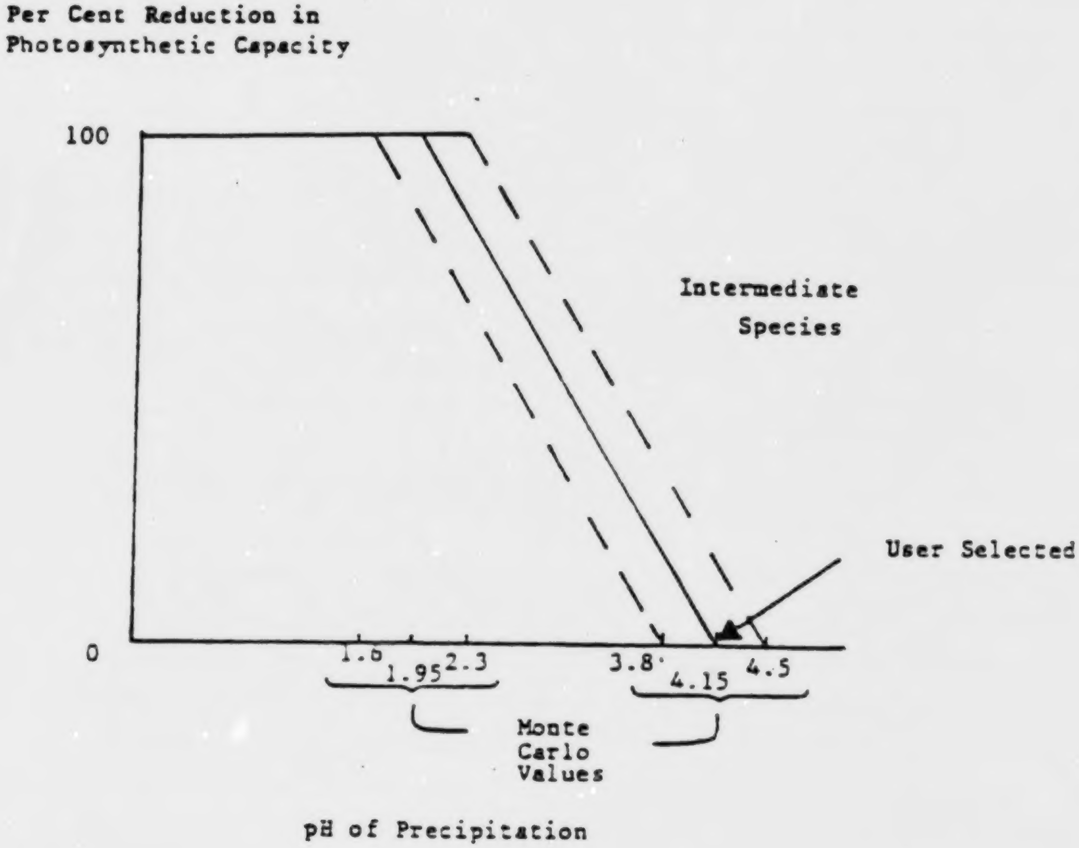


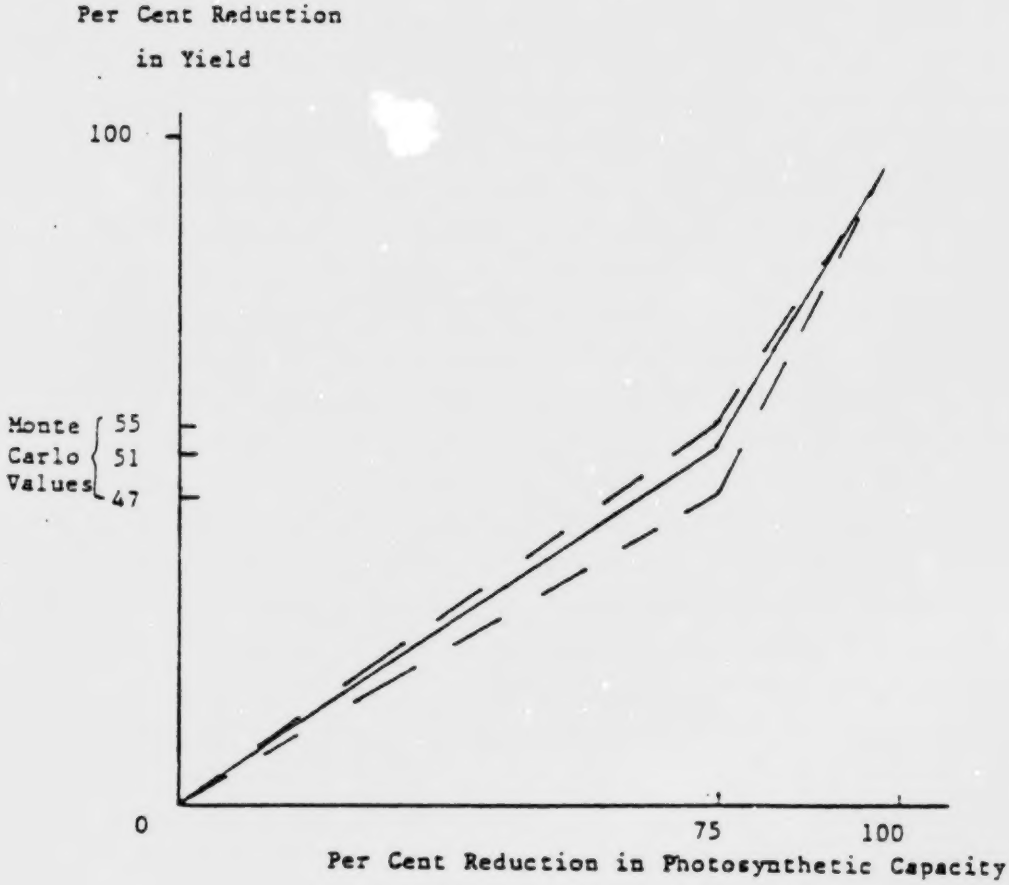
Table of Parameter Values Used in the Computational Framework

	pH of Precipitation
100% Reduction in Photosynthetic Capacity	s: 1.6, 1.85, 2.1 i: 1.6, 1.95, 2.3 t: 1.8, 2.15, 2.5
0% Reduction in Photosynthetic Capacity	s: 4.1, 4.4, 4.7 i: 3.8, 4.15, 4.5 t: 3.0, 3.5, 4.0

s= sensitive species
i= intermediate species
t= tolerant species

Source: Victor and Burrell (1982).

EXHIBIT 3.3: YIELD - PHOTOSYNTHETIC CAPACITY RELATIONSHIP:
FORESTRY (All Species)
(1980 Model)



Source: Victor and Burrell (1982).

3.2.2 Soil Effects

The soil effects operate through three pathways in the 1980 model. They are:

- nitrogen fertilizer;
- nutrient cation leaching (i.e., calcium); and
- toxic effects of the mobilization of metals such as aluminum.

The nitrogen fertilization effect assumes that yield changes are proportional to the application of nitrate to an upper limit (beyond which nitrogen is no longer a limiting element in tree growth).

The basic cation part of the 1980 model uses a mass balance calculation to update the base saturation of the soils annually in response to nitrogen fixation, atmospheric inputs and plant uptake into the trees. The model requires data for each of the 64 sub-regions on: initial base saturation, productive forest land, cation exchange capacity, bulk density of the soils, active soil depth, atmospheric deposition of hydrogen ions, estimate of plant biomass for uptake rates and an estimate of hydrogen ion generated from nitrogen fixation. After updating base saturation each year, the exchangeable calcium concentration of the soils is calculated from the base saturation, cation exchange capacity, bulk density and an estimate of available calcium. The response of forest yields is calculated as a function of the change or loss of exchangeable calcium from the soils.

The final component of the 1980 soils response model relates aluminum in the soils to forest productivity. Available aluminum is assumed to be a function of soil pH, the physical and chemical nature of the soil matrix, the presence of organic substances, and acid loading. Soil pH is predicted from the base saturation calculated in the basic cation part of the model. The effect of aluminum on yield is assumed to be linear; however, the slope and intercept were set to zero in all simulations due to lack of available data on this mechanism.

3.2.3 Economic Valuation

The 1980 model assumes that the effects of acid deposition would not change the volume of wood harvested as the predicted changes in forest yield would not be sufficiently large to change allowable cut regulations. However, it is assumed that the change in forest productivity due to acid deposition would change stand density (either from reduced growth rates or reduced stem density) and consequently, raise harvesting costs per unit volume of wood. The 1980 model includes several forest operation costs that are sensitive to changes in forest density and assumes that proportional changes in productivity (yield) flows through to a commensurate proportional change in these operating cost components. Changes in unit costs are then applied to actual cut figures by region to estimate change in total costs.

Currently, forest harvest is not at allowable cut levels for all areas or species. For those area/species combinations where current harvests are below allowable cuts, the model assumes growth in harvest based on extrapolation of production from Crown and patented lands for the period 1940-1966. In the 1980 model, harvests grow beyond allowable cuts for 10 years (for the harvest of over-mature timber) and then fall at the same but negative growth rate until allowable cuts are reached.

In cases where actual cuts already exceed allowable cuts, harvests are projected to decline to reach the allowable cut levels in 10 years.

3.3 Recommended Revisions to Forestry Model

In the original 1980 model, forest effects of acid deposition are summarized through a metric called yield. Yield refers to the volume of harvestable timber, not the volume actually harvested. The term "yield" should be replaced by a term for forest productivity or "potential yield". Potential yield can be measured in cunits per hectare and is affected by changes in stand density, current annual increment, mean annual increment, etc. The volume of wood actually extracted should be referred to as "harvested yield". This change in terminology does not affect the model functionally, but does clarify the distinction between biological (potential yield) and economic (harvested yield) forest production.

3.3.1 Above Ground Effects

Two approaches to modelling above-ground effects of acid deposition were suggested at the workshop. One approach requires the development of a direct dose-response relationship for trees based on empirical data (analogous to the relationships used in the agriculture model). The participants knew of one major experiment involving simulated acid deposition on trees. The study was carried out by the Electrical Power Research Institute and the Tennessee Valley Authority. This reference will be available soon but the general results are that little or no above-ground effect was measured in the pH range of 3.8 to 5.0.

The second approach maintains the mechanistic structure of the 1980 model but updates it with more recent information. This approach models the mechanisms by which acid deposition may affect forest productivity, based on known (or suspected) chemical and biological processes. The following discussion identifies appropriate changes to the 1980 mechanistic model.

The 1980 model incorporates three sensitivity classes. Although species-sensitivity has been detected in seedling experiments (MOE, personal communication), evidence to date does not support the idea of differing sensitivities to acid deposition amongst (mature) tree species.

Recommendation 1: Maintain the model's capability for identifying three sensitivity classes, but introduce a default which reduces the sensitivity classes to one.

When new data become available, or the user wishes to perform sensitivity tests, he/she may activate the three sensitivity classes by specifying species for each class and parameter values to identify differences in sensitivities between classes.

A further modification to the photosynthesis-yield structure was considered. Conceptually, the effects of acid deposition on tree defoliation could be generalized from recent data on the effect of acid deposition on crops. Data from defoliation experiments (i.e., for budworm) can then be used to relate changes in photosynthetic capacity to changes in tree growth or mean annual increment. There is, however, no evidence for foliar effects of acid deposition above the pH levels of 3.5 proposed for the revised model.

Recommendation 2: The intercept on the foliar dose-response relationship (Victor and Burrell report Figure 3.2) should be set to 3.5 so the expected foliar effect of acid deposition will be zero at pH 3.5. Monte Carlo runs using the 1980 structure but with the new intercept could provide an indication of how sensitive the overall model is to this assumption.

The model accounts for effects of acid deposition only. Ozone can also affect above ground forest productivity. These effects could be added to the model by incorporating a linear multiplier to scale the acid deposition dose-response relationship.

3.3.2 Soil Effects

During the model review and workshop, it was suggested that nitrogen and sulfur (not hydrogen ions) should drive the base saturation calculations and that the nitrogen fixation term be dropped.

Recommendation 3: The only recommended change to the base saturation equation is to drop the nitrogen fixation term. Enhanced cation uptake by wood because of the nitrogen fixation is already incorporated by the term dealing with change in potential yield.

Literature on the forest effects of acid rain indicates that acidification will be so subtle that the model should be insensitive to the exact impact mechanisms. However, it is important that the long term effect of acidification on base saturation and yield be maintained.

> For a hypothetical forest soil it was calculated that 100 years of pH 4.0 precipitation would decrease base saturation in the top 20 cm of soil by 20% and would lower the pH of the A2 horizon by approximately 0.6 units if there were no countering inputs of basic materials. (Morrison, 1984)

Recommendation 4: Make the change in potential yield a direct function of base saturation (instead of through changes in exchangeable calcium). Because of a lack of data on the relationship between base saturation and tree growth, this function can be assumed to be linear (the simplest functional form with least data requirements). At the time of this report, we are unable to make any suggestions regarding the parameters.

In the 1980 model, yield was assumed to increase because of fertilization from nitrate depositions. This should be expanded to include other nitrogen compounds and updated to more recent data.

Recommendation 5: The change in current annual increment (CAI) due to nitrogen fertilization can be assumed to be:

CAI = Base CAI * (1 + .0011 * N kg/ha)

This increase in growth should not continue unconstrained; a saturation level at maximum growth increase of 25% over a five-year period should be introduced.

This relationship and saturation level were derived from Foster and Morrison (1983) Table 1, assuming a 25% increase in growth over a five-year period from a single 224 kg/ha application (i.e., 0.25 = .0011 * 224).

At the workshop, there was some discussion of the effects on winter hardiness of fertilization stimulation. The consensus conclusion was that nitrogen deposition rates in Ontario are too low to promote this problem. Also, winter hardiness problems and die-back have only been observed at higher elevations (mountain tops) than are present in Ontario's productive forest lands.

The structure of the calculations of mobile aluminum should be changed to more accurately reflect current understanding of the mechanisms of trace metal solubility (Paul Arp, University of NB, personal communication), but the degree of impact on trees is still in doubt.

Recommendation 6: The amount of mobile aluminum should remain constant until base saturation drops below some critical point. Then all of the hydrogen input can be assumed to liberate aluminum or other trace metals (i.e., Al+++ = 3H+). The calculation of the effect of aluminum on tree growth or yield should remain the same. At the time of this report, we were still unable to find appropriate parameters for the model.

3.3.3 Economic Valuation

Victor and Burrell (1982) state "the approach taken to estimating the economic value of acid deposition impacts on

Ontario's forests [in the 1980 model] assumes that the effect on the total quantity of wood extracted will be unchanged..." As previously noted, this implies that allowable cut regulations would not be changed.

Forest management and harvest levels are now based on the concept of Maximum Allowable Depletion (MAD) instead of annual allowable cut. MAD differs from annual allowable cut; MAD is the "calculated amount of area from which timber may be depleted over the five year term of a Timber Management Plan by any means, including harvesting, fire, insects, disease, inoperability, or because of allocation of the area to other uses..." (Ontario Ministry of Natural Resources, 1986). Allowable cut is the volume of timber which may be cut for commercial use.

Under this system, there are two pathways by which acid deposition could affect a change in the total quantity of wood extracted. First, it could change MAD. MAD is a function of area, age, and time. Time factors include rotation or cutting cycle and regeneration period (i.e., the period between harvest cut and the approval of stand as free-to-grow). Rotation period is based on local conditions and "reasoned judgement by the forest manager, based on some guiding principle, records and experience" (Ontario Ministry of Natural Resources, 1986). Rotation period is also modified by yield tables which relate age and various yield variables such as height, volume, current annual increment (CAI) and mean annual increment (MAI).

Conceptually, a change in one of the yield variables due to acid deposition could affect MAD. Where harvest levels are currently constrained by MAD, a lower MAD could reduce the total quantity of wood extracted. The link between change in potential yield and MAD could be modelled by combining yield table data (e.g., relating CAI to optimum rotation periods) and output from the Ontario Wood Supply and Forest Productivity (OWOSFOP) model which calculates MAD.

However, for the purposes of this model, it is suggested that MAD not be linked with changes in potential yield, but remain invariant to the effects of acid deposition. The reasons are:

- Only significant changes in CAI (e.g., more than 10%) are likely to affect rotation, MAD, or forest stand management because methods of measurement are crude, wood supply is not tightly constrained in Ontario, and actual cut is below MAD in most management units (Ontario Ministry of Natural Resources, personal communication). In the revised biophysical model -- as in the 1980 model -- impacts on potential yield are expected to be small.

- MAD is determined in large part by local judgement factors. These factors may vary over time, may themselves be affected by acid deposition, may overshadow the effect that changes in potential yield may have, and are difficult to model over long time horizons.

- Considerable data and model extensions would be required to endogenize the potential yield/MAD relationship, complexities which are not warranted by the quality of biophysical data and the magnitude of expected effects.

The second pathway by which acid deposition could affect harvest is by changing the quantity of wood available from a given area.

In a particular region, (maximum) harvest is calculated as a given number of hectares (derived from MAD regulations) times cunits per hectare. Although the harvested area remains constant, acid deposition may reduce cunits per hectare, causing a decline in the volume of harvested wood.

In summary, acid deposition could affect the quantity of wood harvested either through management changes in MAD or directly through changes in cunits per hectare. These linkages can be modelled, but the effect is likely to be small for three reasons. First, the biophysical effects of acid deposition on potential yield are expected to be small. Second, any changes in potential yield factors would be small over the time horizon used in the model (at a maximum, changes in CAI will affect forest productivity in the model in only 20 years of a rotation period of approximately 60 years). Third, harvests in the majority of management units are not constrained by MAD regulations.

Recommendation 7: At this time, maintain the assumption that the total quantity of wood extracted will not be affected by acid deposition on the premise that the effect on potential yield is small. However, should scientific evidence suggest otherwise, it is recommended that MAD be linked with changes in potential yield as outlined above.

In the 1980 model, harvest levels increase at an historic growth rate until constrained by allowable cut regulations. As noted above, allowable cut data is now outdated and should be replaced with MAD information. MAD is available from the Ontario Ministry of Natural Resources for most of the +100 management units for five year periods in 20 year Timber Management Plans. MAD values for the remaining management units will be available after management plans have been approved.

To operate as a constraint on harvest levels, two adjustments must be made to MAD values. First, MAD includes all forms of depletion. Harvest represents just one form of depletion and harvestable area will likely be some portion of MAD. The harvested portion of MAD depends on local factors and, therefore, differs across management units. (Local factors include susceptibility to fire and pest and area allocated to recreational and other uses.) Rough rules of thumb for the harvested portion of MAD could be developed in consultation with foresters in each management unit (John Kus, Ministry of Natural Resources, personal communication). This option should be included in the model, but, until these data can be collected, 100% of MAD will be assumed to be harvestable.

Second, MAD values are given in hectares, while actual cut data in the 1980 model are given in volume units. To enable comparisons of MAD and harvest, actual cut data must be given in area units. These data (with corresponding volumes figures) are available for each management unit from the Timber Sales Branch of the Ontario Ministry of Natural Resources.[1]

In the 1980 model, allowances are made for harvests of overmature lands so that the quantity of wood extracted could exceed allowable cut in any given year. These allowances are subsumed in the MAD calculation by using acceleration factors.[2] Consequently, the value for MAD (adjusted for harvestable portion) should be the only factor used to constrain harvest levels. In the model, actual harvest in year t should be determined by:

$$\text{Actual harvest}_t = \text{Min}[(\text{harvest}_{t-1} * (1 + \frac{G}{100}));(\text{adjusted})\text{MAD}]$$

where Min stands for "minimum"

G is the percent growth rate of harvest.

Recommendation 8: Replace data on annual allowable cut with maximum allowable depletion (MAD) values for five year periods in the 20 year timber management unit planning horizon. When data become available, these figures should be adjusted for harvestable portion. The adjusted MAD provides a control for unconstrained growth of actual cut, as follows:

$$\text{Actual harvest (ha.)} = \text{Min}[\text{harvest previous year (ha.)} * (\text{growth factor}); (\text{adjusted}) \text{ MAD}]$$

Recommendation 9: Update harvest data to correspond to MAD management units. Harvest data to be given in terms of both volume (units) and area (hectares).

In the 1980 model, the economic impacts of acid deposition on forest activities are calculated as:

$$\text{Change in economic welfare} = TC - TC'$$

where TC' are total harvesting costs with acid deposition
TC are total harvesting costs without acid deposition.

This equation is a special case of the general formula for a change in economic welfare[3]:

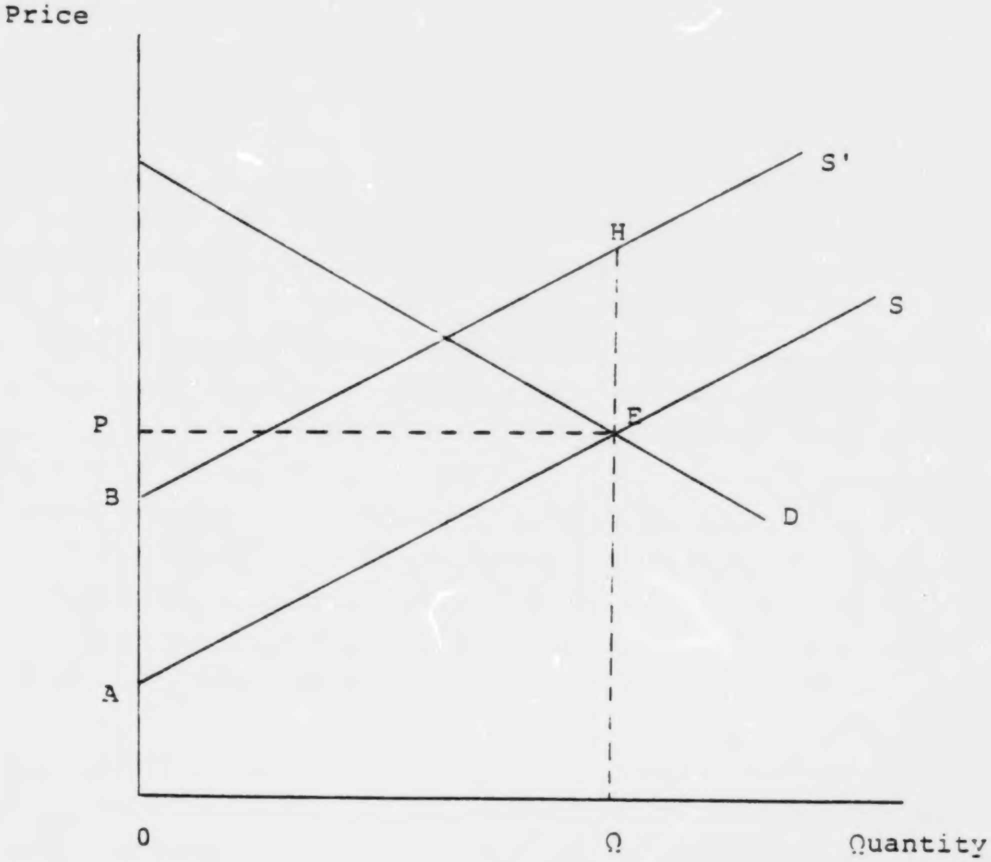
$$P(Q'-Q) + (TC-TC') + .5(P'-P)(Q'-Q)$$

where P is the initial price per unit of wood harvested
Q', Q are the volumes of wood harvested with and without acid deposition, respectively
TC', TC are total costs of harvesting with and without acid deposition, respectively
P' is the new market price associated with Q'

Because the 1980 model assumes $Q' = Q$, then $P(Q'-Q) = 0$ and $.5(P'-P)(Q'-Q) = 0$. Consequently the general formula reduces to $TC-TC'$ which represents a loss in economic welfare when $TC<TC'$ and a gain when $TC>TC'$. The formula used to calculate forestry-related changes in economic welfare due to acid deposition is, therefore, a correct measure under the specified assumptions.

Graphically, the change in economic welfare is given by the area ABHE in Exhibit 3.4. Costs without acid deposition are given by the area under the supply curve S. For quantity Q, total costs are OAEQ. Costs with acid deposition are given by the area under the supply curve S'. For quantity Q, total costs are OBHQ. The change (increase) in costs is, therefore, ABHE.

EXHIBIT 3.4: CHANGES IN ECONOMIC WELFARE IN THE FOREST SECTOR


Price
S'
H
S
P
E
B
D
A
0
Q
Quantity

Because it is assumed that the quantity of wood extracted does not change, the formula used to calculate changes in economic welfare need not be modified. If, however the quantity of wood extracted did change, the economic valuation methodology would have to be modified.[4]

In the 1980 model, changes in total costs (TC-TC') are calculated from volume of wood extracted and changes in delivered wood costs. The model relates changes in delivered wood costs to changes in tree size (which is assumed to be proportional to changes in yield). Total wood costs are disaggregated and forest operation costs which are sensitive to changes in tree size identified. In the absence of better information, the 1980 model assumes that:

- falling, bucking, and delivery (road to mill) costs increase in the same proportion as the decrease in tree size

- delivery costs (stump to roadside) increase by 50% of the decrease in tree size.

In practise, tree size is only one factor in potential yield which may affect costs. Other factors such as number of trees per hectare will also affect costs.

Recommendation 10: Relate changes in delivered wood costs to changes in an appropriate measure of productivity (i.e., potential yield) instead of tree size.

This revised approach requires that proportional changes in cost components used in the 1980 model be reassessed. Necessary modifications can be undertaken in one of two ways. First, the existing breakdown of costs into components (e.g., falling and bucking, overhead, etc.) would be reviewed in order to:

- identify which components are affected by changes in potential yield (not just tree size);

- confirm their share in total costs; and
- revise the assumed statistical relationship between each cost component and potential yield.

Unfortunately, the Ministry of Natural Resources has not modelled delivered wood costs. Most detailed cost information is privileged and belongs to private wood industry companies. A survey of private operators, supplemented with interviews with public sector and industry association foresters, could, however, produce the necessary data for model revisions.

Alternatively, existing forest management models may be accessed. Two models may be particularly useful. The Forest Nutrient Cycling and Yield Trend Evaluator (FORCYTE) model, resident at the University of British Columbia, is a forest management simulator designed to estimate the long-term consequences of intensification of forest management for biomass yield and the economic performance of management strategies (Kimmins, 1985; H. Kimmins, University of BC, personal communication). Because the model is ecologically based and includes an economics package, it could be used to determine the relationship between potential yield and delivered wood costs.[5]

Because of FORCYTE's structure, it is doubtful that equations can be extracted and used in the MOE model. Simulation runs could, however, be performed upon which a generalized relationship between productivity and delivered wood costs could be derived.

The second model -- the modified Timber RAM model -- is resident at the University of New Brunswick. This model was recently used to design management strategies for a timber stand in New Brunswick (Walker and Lougheed, 1985). Model results included:

- maximum volume obtainable;
- minimum cost of producing maximum volume; and

- minimum - cost strategies for progressively lower harvest levels.

Again, equations cannot defensibly be extracted from Timber RAM for use in the MOE model. Simulations could be run, but this exercise would require substantial data collection; documentation on the model suggests it contains virtually no data.

Recommendation 11: It is recommended that a relationship between potential yield and delivered wood costs be developed, based on simulation data from FORCYTE or from a survey of private operators in Ontario's wood industries.

Finally, cost data should be updated. Based on information from Ontario's Ministry of Natural Resources (A. Nausedas, personal communication), average delivered wood costs in 1982 for Northern Ontario boreal forests were about $109 per cunit roundwood, or $120 per cunit in 1985 dollars (using Industry Product Prices for Lumber, Sawmill and Other Wood Products, Statistics Canada).

Detailed cost estimates by region are not available. However, costs for softwood forests -- which account for most of the provincial roundwood production -- are similar. Costs for deciduous forests are somewhat higher, but their share of both volume and value of provincial roundwood production is small. The use of Northern Ontario costs, therefore, is a satisfactory proxy for average costs across the province (A. Nausedas, Ontario Ministry of Natural Resources, personal communication).

Recommendation 12: It is recommended that estimates of unit delivered wood costs be updated to the most current information.

In the 1980 model, for area/species combinations where harvest does not equal allowable cut, forecasts of actual harvest are extrapolated from annual production data for pulpwood, logs and bolts from Crown and patented lands for the period 1940-1966. A rate of increase in roundwood production in Ontario was estimated as 9.56% per year. The past growth rate used in these extrapolations act as a proxy for a variety of factors which determine growth in actual demand, including:

- per capita demand;
- population growth;
- economic growth;
- technology; and
- tastes.

Extrapolation assumes that each of the demand growth factors will behave in the future as they have in the past.

The audit of the existing model identified a further concern with the forecast methodology. Extrapolations for forestry and agriculture are based on different years: agricultural forecasts use production statistics for 1971-1979 while forestry forecasts use statistics for the period 1940-1966. The difference in the base years suggests that the implicit assumptions for future macroeconomic variables (e.g., per capita demand, population growth, economic growth, etc.) will differ for the two sectors. The production and price forecasts for each sector should, to the extent possible, be based on a set of macroeconomic assumptions which is common to all sectors.

Consistency between macroeconomic assumptions may be accomplished by one of two methods. First, extrapolations could be calculated from the same time periods for all sectors. However, a common basis for extrapolation does not consider how the future may differ from the past. This drawback can be avoided by modelling demand based on forecasts of specific macroeconomic factors.

The CANDIDE model, developed by the Economic Council of Canada, provides national forecasts of demand, output and prices for agriculture and forestry. These projections take into account expected changes in population, employment, GNP, and technology. No forecasts are available for sub-sectors within each industry (i.e., the demand for individual agricultural commodities or crops are not forecast) nor are CANDIDE projections disaggregated by province.

The RIM model of Informetrica (an Ottawa based consulting firm), which was developed from the original CANDIDE model, can provide both national and Ontario forecasts of demand, output and prices for the agriculture and forestry sectors. No forecasts are available for sub-sectors within each industry.

RIM projections are readily available through simulation runs by Informetrica; CANDIDE projections are available from the Economic Council of Canada. National indices of production and prices derived from simulation runs from either model can be calculated and used as input to the MOE model.

National growth patterns could then be modified for provincial specifications. Appropriate adjustments may be derived using provincial forecasts or parameters on provincial shares of economic activity from RIM or the Provincial Medium Term Forecasting Model of the Conference Board of Canada, or from historical data on Ontario's changing shares of national output (by sector).

Recommendation 13: It is recommended that indices of future production for forestry be derived from output from the CANDIDE or RIM models. Furthermore, it is recommended that these national projections be adjusted to account for Ontario's changing share of national output, based on historical data or output from RIM or the Conference Board model.

3.3.4 Summary of Recommended Revisions

The revised model for forestry will incorporate two changes to the above-ground components of the 1980 model:

- A default will be introduced to collapse sensitivity classes. The model will maintain the capability to allocate tree species to three sensitivity classes, but these will have to be activated by the user (Recommendation 1).

- The intercept on the foliar dose-response relationship should be adjusted so that expected foliar effects are consistent with the evidence; that is, no effect at pH less than 3.5. (Recommendation 2).

Four revisions to the soils component are suggested:

- The nitrogen fixation term in the base saturation calculations should be dropped as it is already incorporated in the term dealing with change in potential yield (Recommendation 3).

- The change in potential yield should be made a direct function of base saturation, instead of identifying changes through exchangeable calcium (Recommendation 4).

- The nitrogen fertilization calculation should be updated and expanded to include nitrogen compounds other than just nitrate depositions (Recommendation 5).

- No parameters are available to operate the effect of aluminum on tree growth. When data do become available, a saturation level for the amount of mobile aluminum should be introduced (Recommendation 6).

The biophysical effect of acid deposition will be measured as a percent change in potential forest yield.

In the calculations of the economic impact of acid deposition, the model should maintain the assumption that the total quantity of wood extracted will not be affected. However, if scientific evidence indicates significant effects on potential yield, this assumption should be reevaluated (Recommendation 7). Other modifications should:

- change annual allowable cut to maximum allowable depletion (Recommendations 8 and 9);
- adjust changes in wood costs to changes in potential yield (vs. tree size) using output from the FORCYTE model, or survey data (Recommendations 10 and 11); and
- update delivered wood costs (Recommendation 12).

Finally, the growth rate for forest production should be revised, based on output from CANDIDE or RIM macroeconomic models (Recommendation 13).

3.4 Review of Victor and Burrell Recommendations

3.4.1 Above Ground Effects

There were two recommendations dealing with the direct dose-response of forest tree species to acid rain. The recommendations contained in this report more accurately reflect current evidence and thinking. There has been little or no evidence of direct foliar effects of acid rain on trees under conditions experienced in Ontario.

3.4.2 Soil Effects

The relationship between forest productivity and nutrient cations has been changed to include base saturation rather than exchangeable calcium. Unfortunately, the exact form of the relationship is still unknown. A linear relationship has been proposed in the absence of evidence to the contrary.

3.4.3 Economic Valuation

Only one recommendation on the economic valuation of forest impacts was documented in Victor and Burrell (1982). The recommendation was that "the relationship between wood cost and forest productivity be estimated through econometric studies in which other factors are held constant".

As discussed above, simple relationships between wood costs and forest productivity cannot be extracted from existing data. A more likely approach would be to use output from simulation runs of existing models (i.e., FORCYTE) to develop relevant equations for the MOE model. This approach would require more detailed discussions between MOE representatives and staff responsible for operating the model. In particular, the following factors should be explored:

- data requirements to run simulations
- the minimum number of simulation runs needed to derive a reliable relationship (i.e., over various levels of forest productivity)
- the cost of simulation runs
- the stability of wood cost/forest productivity relationship over time.

Discussions should include individuals familiar with timber harvesting operations and forest ecology in Ontario.

3.5 Data Requirements and Availability

3.5.1 Data Requirements

The following data must be assembled to operate the revised forestry model. The preferred disaggregation for each data set are noted:

Data Requirement	Comment	Preferred Disaggregations
1. Soils	new data	by region
2. Harvest/Production (value, volume, & area)	update	by management unit and species
3. Maximum Allowable Depletion (MAD)	new data	by management unit
4. Expected Harvest Portion of MAD	new data	by management unit
5. Delivered Wood Costs (by component)	update	by region
6. Production & price forecasts	substitute data	by region and species

3.5.2 Data Availability

Soils maps prepared by Agriculture Canada can be used to generate all the important soil parameters for the forestry model. A map for southern Ontario is available now and a northern map will be available soon.

Production statistics (including volume/area paired data) are available by management unit from the Ontario Minstry of Natural Resources (John Kus or Hank Van Beers, Timber Sales Branch).

Maximum Allowable Depletion (MAD) values are available for about 60% of the +100 forest management units (contact: John Kus, Ontario Ministry of Natural Resources). MAD values for the remaining management units will be available pending approval of timber management plans.

Data on portions of MAD which are expected to be harvested (vs. lost to fire, pest, allocated to recreation) must be developed in consultation with foresters in individual forest management units. In the interim, the portion is set to 100% for all regions.

Delivered wood costs are not available by region. Provincial average delivered wood costs are approximated from costs for Northern Ontario boreal forests, at about (1985) $120 per cunit roundwood. Wood cost components and their relationship to changes in forest productivity need to be developed from simulation data from the FORCYTE model or from a survey of private private operators. In the interim -- using 1980 values for shares of cost components and sensitivity to changes in tree size -- the cost coefficient used in the model should be changed from (1980)$54.33 per cunit to (1985) $57.89 per cunit or $20.44 per cubic metre.

Detailed discussion with those responsible for the CANDIDE and RIM models should be undertaken to derive new provincial price and production forecast data (see pg. 3-21).

FOOTNOTES

[1] See Statistics 1985: A Statistical Supplement to the Annual Report of the Minister of Natural Resources for the year ending March 31, 1985. Prepared by Ontario Ministry of Natural Resources. For further information, contact Ed. Markus, Director, Timber Sales Branch, MNR.

[2] The acceleration factor is the ratio:

$$\frac{\text{Average age of free-to-grow area (actual forest)}}{\text{Average age of free-to-grow area (normal forest)}}$$

Where an "normal forest" is one which has an even distribution of equally productive areas in all age classes (Ontario Ministry of Natural Resources, 1986).

[3] The general formula is derived in Appendix B.

[4] The appropriate changes in economic valuation with changes in quantity of wood extracted are outlined in Appendix D.

[5] On a more sophisticated level, Dr. H. Kimmins (UBC) suggested FORCYTE could be adapted to simulate the impacts of acid deposition on forests, from deposition levels through to the effects on CAI and wood costs.

4.0 AGRICULTURE MODEL

4.1 Review Methodology

The methodology for the review of the 1980 agriculture model consisted of the same three tasks as undertaken for the review of the 1980 forestry model; that is, an audit of the existing model, a workshop of scientific researchers in the field of acid deposition and a review of the published literature. Somewhat more effort was given to the computer search component of the literature review than in the forestry section, as reviews of crop-related research had not been undertaken by the project team's specialist advisors.

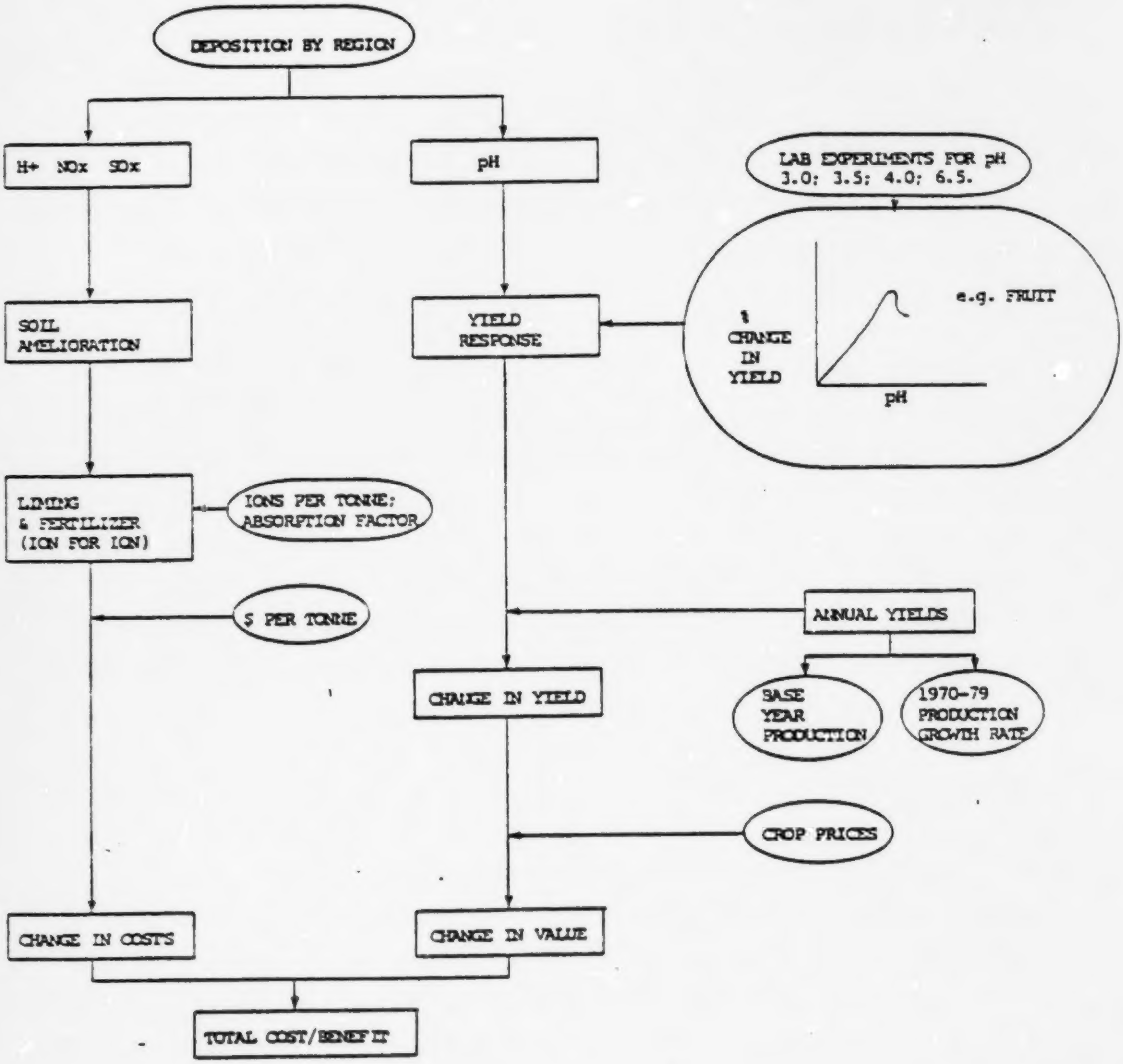
4.2 Description of the 1980 Model

The 1980 model considers the effects of acid deposition on agriculture through two pathways (see Exhibit 4.1). One pathway models the direct (foliar) effect of acid rain on the commercial yield of agricultural crops. These effects are captured in "dose response" relationships that relate the average pH of rain to a proportional change in crop yield. The second pathway models the effects of acid deposition on soil management.

4.2.1 Foliar Response

In the foliar response or above ground component of the 1980 model, each of the commercially grown crops in Ontario (as reported by the Ministry of Agriculture and Food) were assigned to one of eight relative sensitivity groups: root crops, leaf crops, cole crops, tubers, legumes, fruit bulbs, and grains and forage grasses. The assignment was made on the yield change data available at the time and not on taxonomic relationships. For example, rutabagas and cabbage are both from the genus Brassica; however, rutabagas were placed in the root crop category because the root is the

EXHIBIT 4.1: 1980 AGRICULTURE MODEL


DEPOSITION BY REGION
H+ NOx SOx
pH
LAB EXPERIMENTS FOR pH 3.0; 3.5; 4.0; 6.5.
SOIL AMELIORATION
YIELD RESPONSE
% CHANGE IN YIELD
e.g. FRUIT
pH
LIMING & FERTILIZER (ION FOR ION)
IONS PER TONNE; ABSORPTION FACTOR
$ PER TONNE
ANNUAL YIELDS
CHANGE IN YIELD
BASE YEAR PRODUCTION
1970-79 PRODUCTION GROWTH RATE
CROP PRICES
CHANGE IN COSTS
CHANGE IN VALUE
TOTAL COST/BENEFIT

Source: DPA Group Inc.

marketable part while cabbage was placed in the cole crops. The specific crop assignments are as follows:

Root crops - beets, carrots, parsnips, radishes, rutabagas
Leaf crops - lettuce, celery, spinach, tobacco, asparagus
Cole crops - cabbage, cauliflower
Tuber crop - potato
Legumes - green beans, white beans, soybeans
Fruit - apples, cherries, grapes, peaches, pears, plums, raspberries, strawberries, peppers, cucumbers, tomatoes
Bulbs - onions
Grain and Forage Greens - wheat, oats, barley, fodder corn, sweet corn, green corn, hay, mixed grains

The yield response data used is presented in Exhibit 4.2. These data were combined from experimental results (Lee et. al., Evans et. al., 1980; Irving and Miller, 1978; Jacobson, 1980) to produce representative curves for each crop group. The broken lines in the exhibit panels show the variation assumed in the Monte Carlo option.

The Victor and Burrell report (1982) outlines several assumptions and limitations to the model. Most of these relate to the extrapolation of the simulated response data to the field conditions that exist in Ontario.

One major problem with the two pathway structure of the model is potential double-counting of fertilizer effects. Stimulated yields in some of the crops are attributed to fertilization, yet the soils model assumes the farmer will reduce regular fertilization to exactly offset higher deposition of nitrogen and sulphur compounds.

4.2.2 Soil Effects

In the 1980 model, deposition consists of hydrogen, sulfate, nitrate, and ammonium ions. The soils model assumes that farmers will compensate exactly for the effects on the

EXHIBIT 4.2: DOSE - YIELD RESPONSE CURVES: pH OF RAINFALL AND YIELD OF AGRICULTURAL CROPS (1980 MODEL)

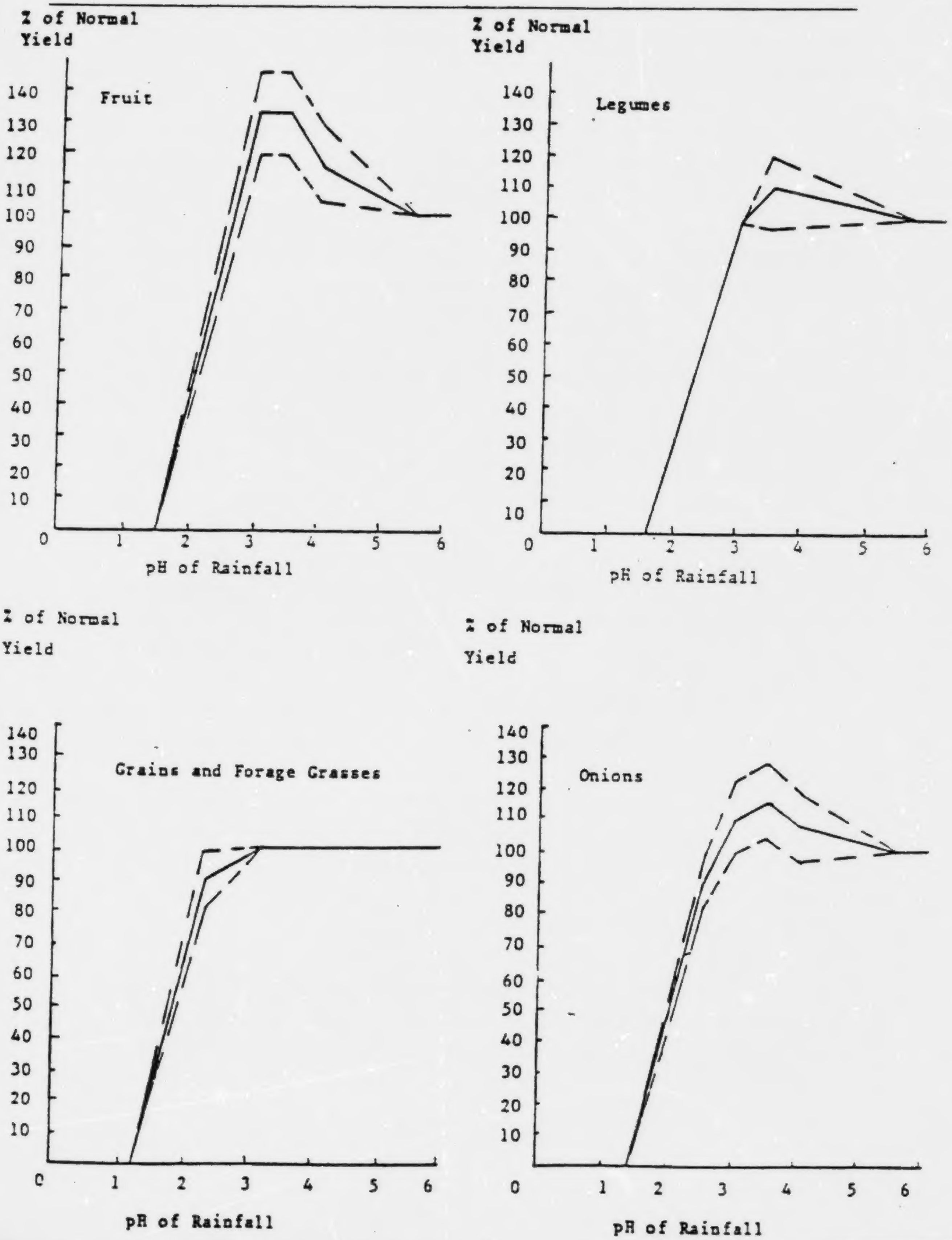
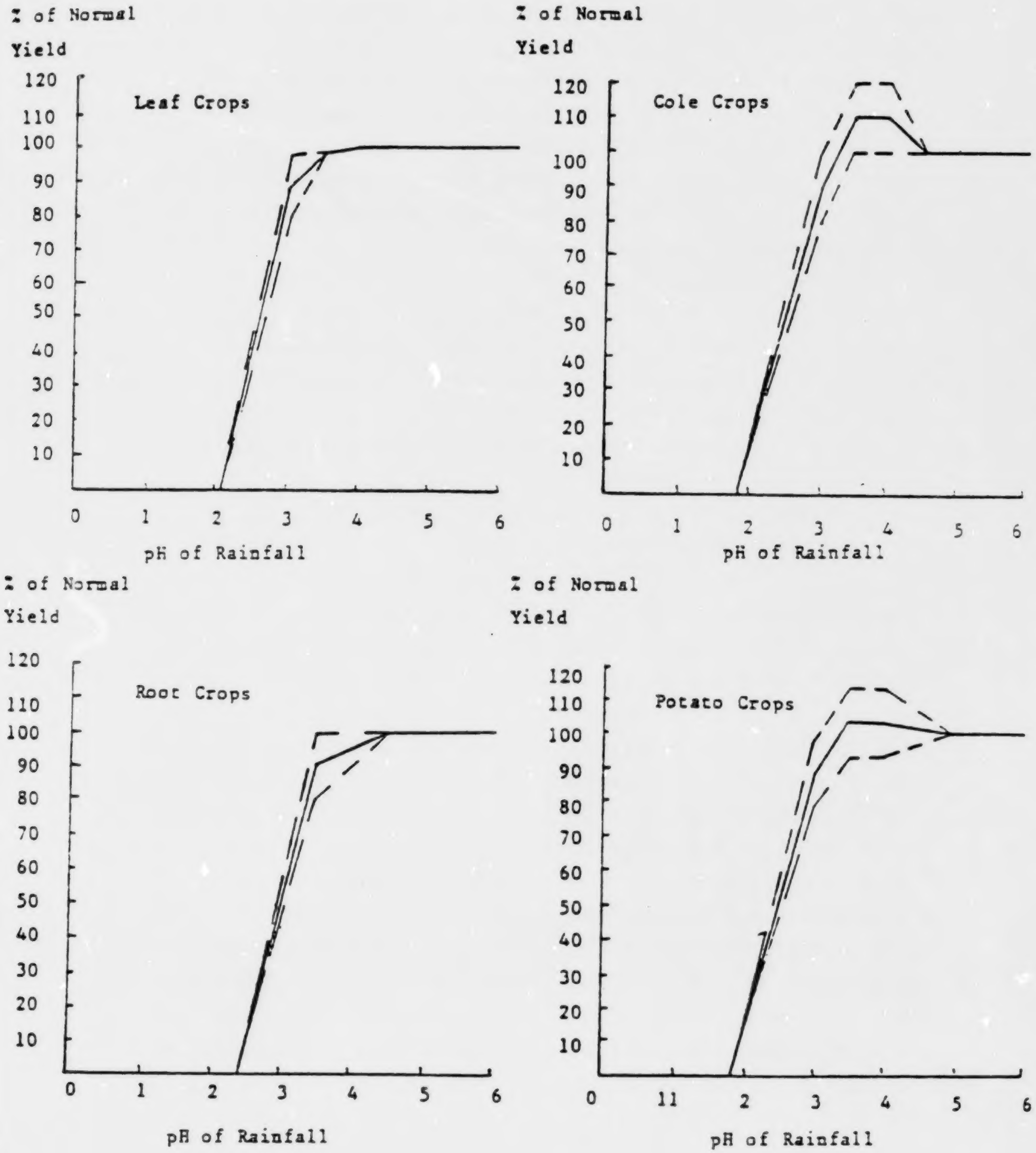


EXHIBIT 4.2: DOSE - YIELD RESPONSE CURVES: pH OF RAINFALL AND YIELD OF AGRICULTURAL CROPS continued (1980 MODEL)



Source: Victor and Burrell (1982).

soil; sufficient lime will be added to the soil to neutralize the direct acidity of the deposition and there will be reductions in the amounts of fertilizer applied to account for the higher levels of nitrogen and sulfur in the precipitation. The amounts of additional lime used or fertilizer displaced is calculated on an ion for ion basis; each hydrogen ion equivalent of acidity from the precipitation will be neutralized by an equivalent amount of lime. Similarly, each nitrogen and sulfur atom from precipitation is available and used to fertilize crops. Therefore, effects of acid deposition mediated through the soil do not affect crop yields; they only affect the cost of soil management.

4.2.3 Economic Valuation

Two economic impacts of acid deposition are included in the 1980 agriculture model:

- changes in revenues associated with changes in yield; and
- changes in costs associated with changes in soil amendment practices.

To estimate changes in revenue, the 1980 model includes a prediction of future agricultural production. These predictions are made by extrapolating recent growth rates (1971-1979) in the production of each crop through to 1990 then reducing all the growth rates by a factor of 2 for the rest of the century to account for limitations on land. The growth rates are applied to 1979 production data, adjusted for geographic regions. Yield reductions are valued at 1980 provincial average prices. It is assumed that changes in yield will have only an insignificant effect on harvesting costs; therefore, changes in harvesting costs are not modelled.

The 1980 model's calculation of changes in gross yield does not reflect potential effects on the quality or marketability of the product. Small imperfections on the surface of high value crops such as fruits and vegetables caused by acid deposition could affect prices instead of yield volumes.

Changes in soil management costs value limestone and fertilizer at 1980 prices. No allowance is made for changes in the cost of applying limestone and/or fertilizer.

4.3 Recommended Revisions to Agriculture Model

The 1980 agriculture model was separated into three components which addressed above ground effects, soil management, and economic evaluation. Although this approach should be maintained, details of these components should be modified. Suggested revisions are outlined below. At the workshop, it was agreed that a better name for the foliar response component was above ground response.

4.3.1 Above Ground Effects

The 1980 model dealt with above ground effects by using different pH dose-yield response curves, for 8 different crop groups. These response curves were applied to the production of 36 individual crops allocated to eight groups (see Exhibit 4.2). Recent studies have contradicted these results (Irving 1983) and suggest that there is little or no consistent evidence that acid deposition affects crop yields.

However, these data are variable and both negative and positive responses have been observed. Negative responses have been observed for some cultivars of soybeans. These varieties are not grown in Canada but, on the other hand, not all varieties grown here have been tested. Positive responses have been observed in some field crops. These crops are not usually fertilized and the response could come from nitrogen or sulfur contained in the deposition. From the workshop and subsequent enquiries, we concluded there are little data to support systematic differences in sensitivities among the crop types grown in Ontario.

Recommendation 1: A single stochastic dose-response relationship for all crops should be used. A review of dose-relationships presented in Irving (1983) forms the basis for this function.

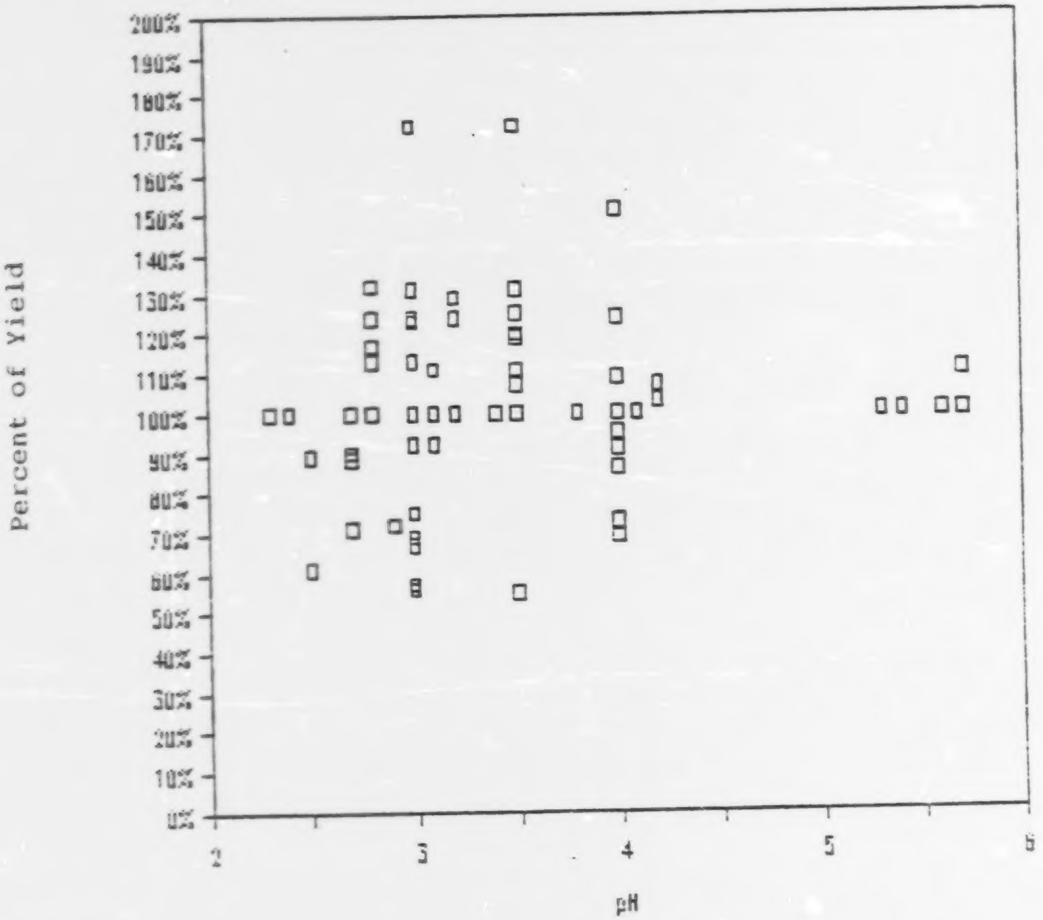
Exhibit 4.3 presents the percent change in yield as a consequence of pH doses measured in 15 field and 34 controlled environment studies of a wide variety of agricultural crops. Exhibit 4.4 presents the same information, except the pH data have been rounded to the nearest .5 level.

Using these data one can calculate a maximum, minimum, mean and variance of the change in yield, for various pH levels (Exhibit 4.5 below). The model should be run in a deterministic mode using interpolated curves through the minimum and maximum for the purposes of comparison with the mean.

The model should also be run in a stochastic or Monte Carlo mode using the mean and variance estimates given below. The user should be able to chose the type of probability distribution for random variation (e.g., uniform, normal, or triangular). The user should also be able to specify whether the variation is correlated across crop types or not.

Recommendation 2: The stochastic dose-response relationship should use the mean and variance estimates from Exhibit 4.5. The user should chose both the type of probability distribution for random variation and whether the variation is correlated across crop types or not. The default should be a normal distribution with correlated variations.

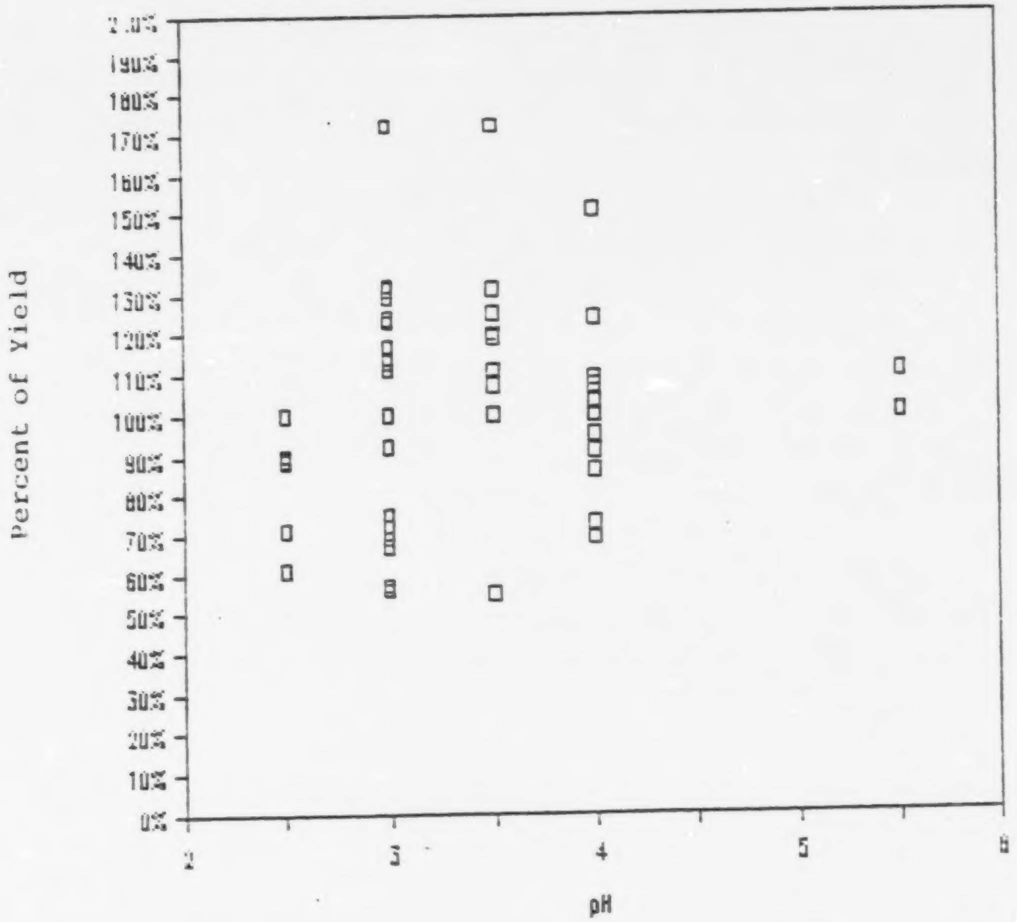
EXHIBIT 4.3: DOSE - YIELD RESPONSE CURVE
DATA FROM IRVING (1983)



Note: Each square may represent several observations.

Source: Irving (1983).

EXHIBIT 4.4: DOSE - YIELD RESPONSE CURVE
(pH DATA ROUNDED TO NEAREST .5)



Note: Each square may represent several observations.

Source: Irving (1983).

EXHIBIT 4.5: MEAN, VARIANCE, MAXIMUM AND, MINIMUM FOR DOSE-YIELD RESPONSE

	pH 3	pH 3.5	pH 4	pH 5.5
Mean	101.58%	103.51%	100.16%	100.19%
Variance	3.09%	2.17%	1.04%	0.02%
Maximum	172.00%	172.00%	151.00%	110.00%
Minimum	56.00%	55.00%	69.00%	100.00%

Source: Irving (1983).

Sugar Maples: Sugar maples yield both agricultural and forestry products. The effect of acid deposition on the forest products is subsumed in the forestry model. Only above ground effects of acid deposition are relevant for agricultural production from sugar maples. The general agriculture dose-response relationship for above ground effects for sugar maples is suggested at this time as no other defensible relationship exists. Sugar maples are not fertilized as are other agricultural products which are included in the model, so changes soil amendment practices are not relevant.

Recommendation 3: Add sugar maple as a crop type, subject to the same dose-response relationship as other crop types for above ground effects. Soil management effects should be set to zero.

The model accounts for effects of acid deposition only. Ozone can also affect above ground crop productivity. These effects could be added to the model by incorporating a linear multiplier to scale the acid deposition dose-response relationship or by adding dose response relationships specific to ozone when they became available.

4.3.2 Soil Management

The major assumption of the 1980 agricultural soils model is that farmers will compensate exactly for the effects of deposition so as to maintain the same soil chemistry. Although the Ministry of Agriculture and its extension program do provide ongoing soil analyses and advice, it is questionable that all farmers will choose or will be in a position to take advantage of this knowledge and that acid deposition will be exactly offset. To estimate the degree to which changes in soil management practices do offset deposition would require behavioural analyses which are tasks beyond the scope of this study. The bold assumption that farmers compensate exactly, therefore, has to be retained for the time being.

The 1980 model simply calculates the amount of nitrogen and sulfur fertilizer additions replaced by deposition and the amount of extra lime required to neutralize the hydrogen ion deposition. This method is acceptable if the additions of ammonium, nitrate and sulfate from soil management exceed the current deposition rate.

This assumption holds true for some fertilizers, but not for sulfate. Most parts of the province require 10-30 kg/ha of sulfate fertilizer (Ontario Ministry of Food and Agriculture, personal communication). These levels are being provided by current levels of acid deposition; sulfate over and above this level is currently added to agricultural soils only in the northwest region of the province (which accounts for less than 1% of total provincial production). Therefore, sulfate deposition up to 10-30 kg/ha only should be included as a benefit of acid deposition. Any sulfate deposition in excess of 10-30 kg/ha is not included as either a benefit (as required levels are already reached) or as a cost (as offsetting additives are not needed).

Recommendation 4: Sulfate deposition up to 10-30 kg/ha (using 20 kg/ha as a default) substitutes for sulfate fertilizer applications. It reduces costs and should, therefore, be included as a benefit of acid deposition. Sulfate deposition above this level should be included as neither a benefit nor cost of acid deposition. (Note: Additional liming attributed to sulfate deposition above 20 kg/ha is accounted for in Recommendation 5.)

Coote et al (1986) present a model of agricultural soils that accounts for the acidifying effect of sulfur. The additional liming requirement to offset the acidifying effect can be calculated as follows:

$$H^{+} = 2 * SO4^{--} * [a * l - r]$$

where:

l is the proportion leached.
a is the proportion of leached cations that are basic.
r is the proportion removed by plant harvest.

In Coote's paper, estimates are presented for l and r for an Ontario research farm. These are .7 and .3 respectively. The parameter a is assumed to be related to base saturation (BS). The relationship used by Cootes is as follows:

$a = 0.026 * BS - 0.000164 * BS2 - 0.078$ for $20\% < BS < 80\%$
$a = 0$ for $BS <= 20\%$ and
$a = 1$ for $BS >= 80\%$.

Recommendation 5: The effect of sulfate deposition accounted for in the liming requirements should be equal to hydrogen ion input plus a component for sulfate deposition.

No changes in the treatment of nitrogen fertilizing are suggested.

4.3.3 Economic Valuation

The combination of soil and above ground effects of acid deposition will result in changes in the application of lime and fertilizer and in changes in yield (production). Consequently, total costs of production as well as gross revenues will change. The 1980 model assumes that prices are not affected by changes in yield or costs and calculates

$$\text{Change in economic welfare} = P(Q'-Q) + (TC-TC').$$

This formula is a correct measure of welfare change assuming constant prices. This may be shown by substituting the constant price assumption into the generalized formula

$$P(Q'-Q) + (TC-TC') + .5(P'-P)(Q'-Q)$$

If prices are constant, $P = P'$, $P-P' = 0$ and the third term drops out of the generalized formula leaving

$$P(Q'-Q) + (TC-TC')$$

Graphically, the change in economic welfare is represented as the area BAEDC in Exhibit 4.6.[1] The exhibit has been drawn to show a decrease in costs and an increase in yield and, therefore, an overall gain to economic welfare as a result of acid deposition. These impacts are shown as positive for two reasons:

- they offer a different perspective of changes in economic welfare from forestry-related impacts; and
- scientific literature suggests that several crop types, will, in fact, benefit from deposition.

If changes in crop yield affect prices (e.g., increased yields reduce market prices), the formula used in the

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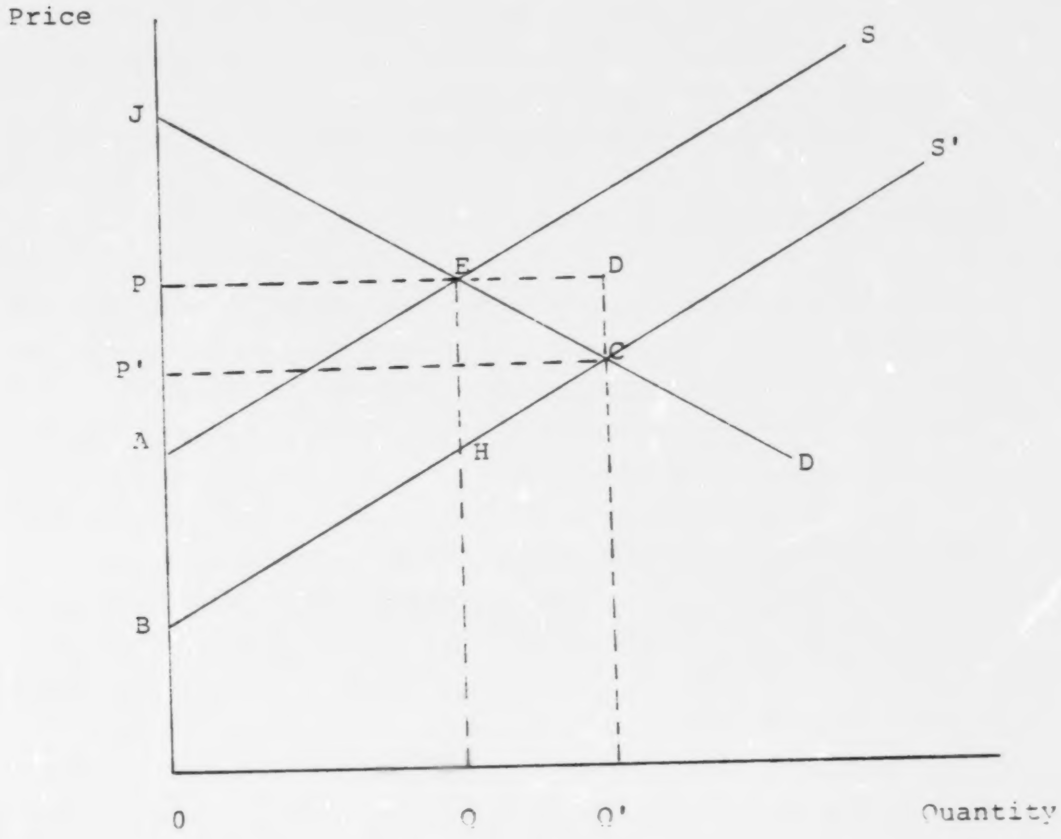
EXHIBIT 4.6: CHANGES IN ECONOMIC WELFARE IN THE AGRICULTURE SECTOR


Price
S
J
S'
E
D
P
C
P'
A
H
D
B
0
Q
Q'
Quantity

1980 model will bias the estimate of the change in economic welfare due to acid deposition. The extent of the bias is illustrated in Exhibit 4.6. As noted above, the current formulation calculates the change in economic welfare as the area BAEDC. When price effects are taken into account, the change in economic welfare is shown by the area BAEC[2]. In this example, $P(Q'-Q) + (TC-TC')$ would overestimate the economic benefits of acid deposition by the area EDC. The area BAEC can be calculated using the general formula

$$\text{Change in economic welfare} = P(Q'-Q) + (TC-TC') + .5(P'-P)(Q'-Q).$$

Recommendation 6: It is recommended that the formula $P(Q'-Q) + (TC-TC')$ be replaced with the general formula for estimating changes in economic welfare, to enable the user to take into account possible changes in market prices of affected agricultural products[3].

The following paragraphs review methods by which each component of the generalized formula may be estimated for agriculture.

Initial Quantity and Price (Q,P)

Initial quantities and prices can be collected from statistics on current production and price levels.

Harvest Levels Adjusted for Acid Deposition (Q')

Acid deposition may affect agricultural yields in two ways. First, total harvested yield may change; second, total marketable yield may change. Changes in total harvested yield are derived from dose-response relationships. Marketable yield takes into consideration changes in quality which may affect the proportion of harvestable yield which can be sold at the prevailing price.

Quality effects may be manifested either by changes in the actual quantity going to market or by changes in price. For example, tomatoes which are blemished as a result of acid deposition may have to be sold at a discount price or withdrawn from the market completely. The magnitude and nature of quality effects is determined by a complex combination of factors, including:

- the nature and the extent of the blemish
- demand characteristics for the product
- marketing methods
- availabilty of unblemished product.

Quality effects on the economic value of agricultural produce are highly case-specific. We know of no data or model which can provide a functional relationship between changes in quality and price/quantity sold which would be useful to the MOE models. Furthermore, appropriate biophysical data is not available .

Recommendation 7: It is not recommended that the model include quality impacts as adequate biophysical data and price relationships do not exist.

Changes in Total Cost (TC-TC')

The 1980 model uses regional average soil amendment prices for:

- agriculture limestone
- sulfur fertilizer
- nitrogen fertilizer.

Recommendation 8: It is recommended that soil amendment prices be updated to the most recent available data using information from the Ministry of Agriculture and Food.

The 1980 model assumes that farmers will be fully aware of changing soil amendment requirements and will respond accordingly. As noted above, this is a bold, but necessary, assumption. To the extent that farmers do not adjust soil management practices (but, for example, apply too much fertilizer and too little lime) the economic values of acid deposition will be biased.

Recommendation 9: It is recommended that the current assumption that all farmers will adapt soil amendment practices perfectly be maintained. However, it should be noted that cost savings due to acid deposition are likely to be overestimated or higher costs underestimated.

Modification for Changes in Consumer Surplus [.5(P'-P)(Q'-Q)]
As discussed in Appendix B, the calculation of this portion of the change in economic welfare requires an estimate of the (own price) elasticity of demand in order to calculate the new price P'.

The new price (P') is calculated from quantity change data (Q, Q') and the elasticity estimate (e) as:

$$\text{Percentage change in price} = \frac{\text{percentage change in quantity}}{\text{elasticity}}$$

$$\Delta P = \frac{\Delta Q}{Q}\,\frac{P}{e};\ \text{and}\ P' = P + \Delta P$$

Estimates of consumer demand for food commodities, including estimates of demand elasticities for major food products, are documented in an Agriculture Canada research report (Hassan and Johnson, 1976). Estimated own price elasticities are given in Exhibit 4.7. Of particular interest to the MOE model are the demand equations for cereals and fresh fruits. The study also reports own price elasticities for fresh vegetables drawn from a previous study.

There are some limitations in using these elasticity estimates. First, the commodity groups in the study are either highly aggregated or do not correspond to the

EXHIBIT 4.7: PRICE ELASTICITIES[a] AND EXPENDITURE PROPORTIONS FOR 27 FOOD COMMODITIES

Commodity	Price Elasticity	Expenditure Proportion
Beef	-.8522	.037434
Pork	-.9547	.024912
Lamb	-1.866	.000844
Veal	-2.593	.001549
Chicken	-.5637	.007593
Turkey	-1.090	.002629
Fish	-.7929	.00477
Eggs	-.1207	.007204
Cereals[b]	**-.20**	**.037481**
Fluid Milk	-.4390	.018682
Butter	-.8583	.00662
Cheese	-.9077	.004965
Skim Milk Powder	-.1924	.000587
Other Dairy Products	-.33	.006627
Margarine	-.6276	.00187
Lard	-.4628	.000187
Shortening	-.9680	.001528
Salad Dressing	-.927	.001174
Fresh Fruits[b]	**-.4546**	**.012267**
Canned Fruits	-.7498	.005744
Fresh Vegetables[b]	**-.2420**	**.011974**
Canned Vegetables	-.3215	.006328
Sugar	-.24	.001538
Beverages	-.3726	.012558
Frozen Foods	-1.0319	.003373
Prepared Foods	-.6710	.005346
Miscellaneous Foods	-.1244	.009116

Notes:

[a] Price elasticities relate percent changes in quantity and percent changes in price:

$$\text{elasticity} = \frac{\%\Delta \text{ quantity}}{\%\Delta \text{ Price}}$$

[b] Estimate of particular usefulness to model revisions.

Source: Hassan and Johnson, 1976

specific categories included in the MOE model. The degree to which estimates may be aggregated or generalized requires further investigation. Second, the Agriculture Canada study does not include any non-food agricultural products such as tobacco.

In summary, estimates of elasticity of demand do exist and can be used to estimate the impact on economic welfare due to acid deposition. However, considerable attention must be paid to matching available elasticity estimates to commodity groups specified in the MOE model.

The importance of the term, .5(P'-P) (Q'-Q), depends on price sensitivity of the market. Where prices are not affected by changes in quantity produced, this last term is not needed. Conditions under which prices will likely not change include:

- institutionally controlled prices (e.g., marketing boards);
- small (e.g., less than 5%) changes in quantity;
- international or large markets where changes in domestic production are small relative to total quantity produced (i.e., producers face a perfectly elastic demand curve).

Recommendation 10: The user should activate price effects where prices are quantity sensitive by specifying an elasticity for each crop group. The model default should set .5 (P'-P) (Q'-Q) equal to zero.

Considerations in developing forecasts of agricultural prices and quantities in the absence of acid deposition are similar to those for forestry (see Section 3.3.3). In particular, an attempt should be made to ensure that:

- the basis on which forecasts are developed is consistent across sectors
- forecasts incorporate projections of macroeconomic variables.

As discussed in Section 3.3.3, CANDIDE and RIM macroceonomic demand models provide forecasts of demand, output and prices for the agricultural sector in Canada. These forecasts could then be modified to reflect Ontario's changing share in the national output and further refined for specific product types based on changing shares of total agricultural output. Although this approach forsakes some species and regional detail, it does ensure that price and output forecasts are consistent across sectors and future macroeconomic trends are taken into account.

Recommendation 11: It is recommended that projections of prices and output for the agricultural sector be accessed from the CANDIDE or RIM models. Modifications of growth trends should then be made to reflect provincial and species-specific changes in shares of agricultural output. The RIM or Conference Board models could assist in developing provincial specifications.

4.3.4 Summary of Recommended Revisions

It is suggested that maple sugars be added as a 37th crop type. Impacts due to acid deposition are included only in the above ground component, because sugar maple trees are not fertilized as are other agricultural crops. Soil impacts on sugar maple trees are embedded in the forestry model. (Recommendation 3).

Revisions to the agricultural model are suggested for above ground and soil impacts, as well as economic valuation. For above ground effects, updated information does not support the 1980 dose-response relationships. Instead, it is recommended that a single stochastic dose-response relationship for all crop types be used. The function should be based on the mean, variance, minimum and maximum impact values from a survey of dose-response relationships (Irving, 1983). The form of the stochastic variation (e.g., normal, uniform, triangular distributions) and correlation between crop types should be specified by the user, with defaults built into the model. (Recommendations 1 & 2).

In the soil management component, revisions relate primarily to the modelling of sulfate fertilizer amendments. The 1980 model calculates the amount of sulfur fertilizer additions replaced by deposition on an ion by ion basis. However, only 10-30 kg/ha is required on most Ontario agricultural soils, so that only sulfate deposition up to this level should be included as a (beneficial) impact. Sulfate deposition above this level should be considered as neither a benefit nor a cost (Recommendation 4).

The effect of sulfate deposition on liming requirements should be equal to the hydrogen ion input plus a component for sulfate deposition. Incremental liming required to offset the acidifying effect of sulfur should be calculated using an updated equation from Coote et. al. (1986) (Recommendation 5).

Recommended revisions to the economic valuation of agricultural impacts are:

- incorporate price effects to capture changes in economic value arising from price changes (Recommendation 6). These effects should be activated by the user by specifying a price elasticity for each crop group (Recommendation 10). The default should set price effects equal to zero.

- update soil amendment costs (i.e., fertilizer prices) to most recent available data (Recommendation 8).

- amend forecasts of agricultural production in the absence of acid deposition with output from macroeconomic models to maintain consistency of future trends with other sectors (Recommendation 11).

A review of quality impacts on agricultural produce concluded that their valuation is highly case-specific and cannot be reasonably estimated. Therefore, quality impacts should not be incorporated into the model (Recommendation 7). It is also noted that farmers may not adapt soil management practices but that is assumption should maintained in the absence of better information (Recommendation 9).

4.4 Review of Victor and Burrell Recommendations

4.4.1 Above Ground

Most of the Victor and Burrell recommendations involved improving the dose-response relationships. Since the Victor and Burrell (1982) report, there has been extensive research done in the United States on the direct effects of acid rain on agricultural crops. The major conclusion to be drawn from this research is that effects are likely small and difficult to detect. The changes to the model recommended in this report provide a mechanism to account for the effects while maintaining consistency with experimental results.

4.4.2 Soil Effects

One of the original recommendations was to account for runoff and seasonal effects in the transfer of nitrogen and sulfur deposition to agricultural soils. The exact proportion of the deposited material that remains and enters the agricultural system is still not known with great accuracy although an estimate of 65% of annual wet and dry deposition has been used by Coote and others. This proportion should be left to the user to set, with a default of 65%. Sensitivity to this parameter should be assessed when programming edits have been made. This recommendation is covered in Section 2 of this report (Recommendation 3).

4.4.3 Economic Valuation

Victor and Burrell (1982) forwards two recommendations relevant to the economic valuation of agriculture-related impacts of acid deposition. First, they recommend "that the basic input data be refined according to the 64 regions used". Suggested revisions of data input formatting and regional disaggregations are discussed in Section 6.0 of this report.

The second recommendation is that "the relationships between physical damages and economic value be modified to account for changes in market value". In this recommendation, they suggest that relationships between the physical appearance of produce and market price be explored. As discussed above, these relationships are extremely complex and depend on case-specific factors. To our knowledge, generalized relationships between the physical appearance of produce and market price are not available. Furthermore, adequate biophysical data on quality effects are not available. It is, therefore, recommended that the model not attempt to estimate changes in economic value due to quality impacts.

4.5 Data Requirements and Availability

4.5.1 Data Requirements

The following data must be assembled to operate the revised agriculture model. The preferred disaggregations for each data set are noted:

Data Requirements	Comment	Preferred Disaggregations
1. Soils	new data	by region
2. Fertilizer Application	new data	by region
3. Crop Production (volume, value & area)	update	by region and crop type

4. Maple Sugar production	new data	by region
5. Fertilizer prices (limestone, sulfur and nitrogen fertilizer)	update	by region
6. Price elasticities	new data	by crop type/group
7. Price and production forecasts	substitute data	by region and crop type

4.5.2 Data Availability

Soils data that are appropriate to this model are currently available from Agriculture Canada for southern Ontario. These soil maps are a resolution of 1:1,000,000 and contain 275-300 polygons. Maps for northern Ontario will be available soon.

Unfortunately, fertilizer application data (in volume terms) are not available at any level less than the provincial. Only a very small amount of sulfur-based fertilizer is used in Ontario, almost exclusively in the northwest of the province which accounts for less than 1% of the provincial value of agricultural production (T. Bates, University of Guelph, personal communication). There are no recommended sulfur use areas in Ontario, apart form the northwest region.

Production data by crop type are available on a county basis from Statistics Canada. The Ontario Ministry of Agriculture and Food (OMAF) also has data at this resolution, but it appears to be the same information.

Maple sugar production data are available for nine regions and provincial totals from OMAF. Exhibit 4.8 presents the most recent data.

Fertilizer prices should be updated. These are available at the provincial level from the Ontario Ministry of Agriculture and Food. Regional data are not available. Preliminary prices are[4]:

Agricultural limestone (CaCO3)	$5-$6 per tonne at quarry $15-$25 per tonne applied
Nitrogen-based fertilizer	$500-$700 per tonne at plant $600-$800 per tonne applied
Sulfur-based fertilizer	$35 per tonne wholesale

Note: The retail price of sulfur-based fertilizer is difficult to determine as it is often sold as a mix of fertilizers and/or soil additives.

Price elasticities have been estimated by Agriculture Canada for major food products. Based on the species disaggregations in the 1980 model, the following elasticities are suggested:

Fresh fruits	-.4546
Fresh vegetables	-.2420
Cereals	-.20

Price and production forecast data should be replaced with data from CANDIDE or RIM (see page 4-20). Regional and species disaggregations are not available but could be derived from Statistics Canada production data.

EXHIBIT 4.8: MAPLE SUGAR PRODUCTION STATISTICS

a) Value and Volume for Ontario and Canada (1978-1985)

	Ontario		Canada	
Year	'000 litres	millions $	mil litres	millions $
1978	648	2.2	7.2	19.0
1979	815	3.0	10.7	32.5
1980	468	2.0	11.0	NA
1981	916	4.5	17.0	52.0
1982	932	4.9	9.7	30.0
1983	907	4.3	12.3	38.4
1984	839	4.6	8.2	29.6
1985	1,003	5.7	10.4	NA

b) Regional Distribution in Ontario (1984)

Region	Percent of Provincial Production
Waterloo-Dufferin	12
Parry Sound	9
Algoma & North	6
SW Ontario (Niagara)	11
Central Ontario (Muskoka, Haliburton, Simcoe Counties)	15
Renfrew County	3
Peterborough	6
Ottawa	8
Leeds & Lanark Counties	20
Miscellaneous	10

Source: Bill Langdenburg, Ontario Ministry of Agriculture and Food, personal communication.

FOOTNOTES

1. The change in economic welfare under constant price assumptions is derived as follows:

   Change in producer surplus = new producer surplus (BPDC in Exhibit 4.6) less original producer surplus (APE in Exhibit 4.6).
   The net change in producer surplus is the area BAEDC.

   There is no change in consumer surplus as it is assumed that prices do not change. The increase in economic welfare, therefore, is the area BAEDC.

   It can be shown that the area BAEDC can be calculated by the formula P(Q'-Q) + (TC-TC') as follows:

   P(Q'-Q) is the area QEDQ' in Exhibit 4.6 which can also be expressed as QHCQ' + HEDC.
   (TC-TC') is represented by the areas OAEQ - OBCQ' which can also be expressed as OBHQ + BAEH - OBHQ - QHCQ' or BAEH - QHCQ'.

   Combining the two measurement components gives

   HEDC + QHCQ'
   + BAEH - QHCQ' or BAEDC.

2. The change in economic welfare with changing prices is derived as follows:

   Change is producer surplus
   = new producer surplus less orignial producer surplus
   = BP'C - APE (Exhibit 4.6)

   Change in consumer surplus
   = new consumer surplus less orginial consumer surplus
   = P'JC - PJE (Exhibit 4.6)
   = P'PEC

   Change in economic welfare
   = change in producer surplus plus change in consumer surplus
   = BP'C - APE + P'PEC
   = BAEC

3. As discussed in Appendix B, the term .5(P'-P) (Q'-Q) measures the price effects where demand and supply curves are linear. It gives an approximate measure when demand and supply curves are non-linear.

4. Sources are:

   Tom Bates, Land Resource Science Branch, University of Guelph.
   Jim Brown, Canadian Fertilizer Institute.

5.0 HUMAN SYSTEMS MODEL

5.1 Review Methodology

The review of the human systems model was based on a survey of the recent published literature, supplemented by telephone interviews with key researchers and practical professional experience. Abstracts of technical papers and articles were examined to:

- verify that the premises on which the 1980 model is based are correct; and
- identify possible revisions to the approach and, where appropriate, to corrosion formulae used as dose-response relationships.

The literature search covered nine databases, using ten key words:

acid rain
buildings
steel
zinc
weathering
corrosion
masonry
copper
aluminum
monuments

The databases accessed were: Enviroline, Compendex, Metadex, Pollution Abstracts, NTIS, Acidoc, Environmental Bibliography, Chemical Abstracts, EPRI.

Initially, more than 360 abstracts were reviewed which generated 39 papers of preliminary interest. Some of these were found to have little relevance, but others revealed references not previously located. Finally, over 500 abstracts were reviewed, and 36 references used in this study.

5.2 Description of the 1980 Model

The 1980 model proposes dose-response relationships and economic impact formulae for:

concrete	copper
zinc	paint
aluminum	nickel.

Model documentation also discusses historical buildings and structures, and water supply systems.

In the 1980 analytical framework for buildings and materials, dose-response relationships are embodied in "interaction values" -- values which relate SO2 concentrations to rates of corrosion. SO2 concentrations are calculated from data on sulfate deposition. Changes in interaction values then may increase maintenance requirements and/or rates of replacement; the associated economic impacts are calculated using a model derived from Salmon (1970). This approach requires region-specific data on population and deposition. Provincial data are required for materials consumption, economic life, value added and exposure factors and interaction values. The specific damage for a region in Ontario is given by:

$$D_r = C \times L \times V \times E \times P_r \times I_r$$

Where:

D_r = Annual damages in region r (1980$)
C = Consumption of material in Ontario in 1979 (1980$)
L = Estimated economic life of the material
V = Value added factor to reflect materials value in place
E = Exposure factor (%, wet deposition only)
P_r = (Population in region r)/(Ontario population)
I_r = Interaction Value (determined by SO_2 levels in region r)

Dose-response relationships used in the 1980 model were gathered from general studies on the effects of air pollution on buildings and materials. Dose-response relationships specific to acid deposition were not available. Where no recent information was available for a specific material, the 1980 model uses intreaction values in Salmon (1970).

For historical buildings and structures the model discusses the use of both the value of historic structures and the repair and restoration costs, but concludes that the repair costs approach is the only practical means of assessing damage cost.

For water supply systems, a proposed framework was based on the aggressiveness of waters and the necessary additional costs of water treatment. This framework requires input of municipal data (e.g., quantity of chemicals used, labour requirements, ASTM indices, capital costs) to show the trend towards increasing acidity before attributing treatment costs to the effects of acid deposition.

5.3 Conceptual Model for Materials Impacts

There is little doubt that atmospheric pollutants affect concrete and other man-made structures. In Southeast Asia, cracking has been found in over 200 buildings within two years and severe degradation within five years. The attributed cause is high levels of acid deposition (Brookhaven National Lab, 1985).

Quantitative measurement of the effects of acid deposition on human systems, however, is hindered by the complexity of the underlying impact mechanisms. Effects depend on numerous factors, each of which varies with time and location. It is important that, prior to attempting an economic valuation of impacts, degradation and corrosion mechanisms are understood and the defensibility of dose-response relationships evaluated. It is not apparent from the 1980 model that these two criteria have been met.

This section reviews the major factors required in a conceptual model of the impact of acid deposition on materials. The section is intended as background information to guide current and future revisions to MOE's human systems model. The breadth and variability of these factors, which underlie the difficulties in quantifying impacts, are also discussed.

5.3.1 Deposition Considerations

The literature review indicated there is little quantitative information relating the effects of acid deposition on corrosion rates of materials, particularly buildings and stones. For most materials, there is very little recent documentation of rigorous modelling, quantification of impacts, or methodologies for estimating corrosion costs of acid deposition.[1] Available information covers expected general corrosion rates for various metals in urban, rural, industrial, and marine "environments".

A comprehensive study (Brookhaven National Lab, 1985) accessed ten databases and produced only seven references pertaining directly to the effects of acid rain on portland cement concrete (PCC) structures. The study revealed "very little qualitative or quantitative information on the effects of acid deposition on PCC structures" (Brookhaven National Lab, 1985).

Some SO_2/corrosion formulae have been estimated. In these formulae, SO_2 is a surrogate for sulfate (one of the main components of acid deposition). The relationship between SO_2 and sulfate varies over time and location; further, SO_2 includes local as well as long range sources. In using SO_2/corrosion formulae, the model attributes a constant and, therefore, somewhat arbitrary relationship between SO_2 and sulfates.

The second major component of acid rain is NO_x. Although high levels of NO_x will corrode a variety of materials in the presence of moisture, research results suggest that the low to moderate levels of NO_x (as encompassed by the range of deposition we suggest be considered in the revised MOE model) are not likely to have appreciable corrosive effects (Graedel & Schwartz, 1977). Based on the research undertaken for this study, it appears that relationships between NO_x and corrosion have not been estimated.

The Victor & Burrell report (1982) notes that the 1980 model includes wet deposition only. The report also notes that "it has been suggested that dry deposition could be at least as great as wet deposition and that corrosion by dry deposition could on a unit by unit basis be greater." Although data on dry deposition levels in Ontario are now available, corrosion rates associated specifically with dry deposition have not yet been estimated.

Another important consideration regarding acid deposition and related corrosion is to define the area which is exposed. On a concrete bridgedeck, for example, the surface will be covered with asphalt and the underside not exposed to direct deposition; on a steel beam-supported bridgedeck, only the outer faces of steel (which represent only a small percentage of the surface area) may be exposed. To assume that total surface area -- or worse, total volume of steel or concrete in use -- is exposed would overestimate the impact of acid deposition. In calculating materials at risk, therefore, careful attention must be paid to estimating exposure factors -- i.e., to identifying only that area which is exposed to (wet or dry) deposition.

5.3.2 Material Sensitivity

There are a number of factors related to the nature of the exposed material itself which can affect its sensitivity to acid deposition. First, the quality of the material is important. Concrete, even within a particular type, will vary by air entrainment, water to cement ratios, additives, etc. Deterioration of reinforced concrete structures when exposed to chloride is highly dependent on the depth of cover. Where depth of cover is 1/2", fracturing of surface concrete will occur rapidly; where depth of cover is 3" and a good quality of mix used, it may take many years before cracking begins (U.S. Department of the Interior, 1981).

The composition and physical properties of stone and masonry may not only vary from structure to structure, but also within the same structure. The Cologne Cathedral was built using eight different stones, all of which exhibit different vulnerabilities (Reader's Digest, 1986). Susceptibility to acid deposition-related deterioration depends on the type of stone, its chemical components, pore structure and porosity.

Material quality also depends on surface preparation. The quality and properties of surface preparation are particularly important for paints, as they determine bond strength between the substrate and the paint. For example, a well prepared substrate for painting will likely yield a recoating life far greater than that for a poorly prepared surface using the same paint (Weaver, 1975 and Keane, 1966). Where a surface is poorly prepared, substrate metal can be exposed. Corrosion at such locations then leads to undercutting and removal of paint film. This process would occur in the absence of SO_2 for painted carbon steel. Thus, it is exceedingly difficult to estimate what paint damage is caused by SO_2. The isolated effect of SO_2 on paint products could be quantified through laboratory research; however, relating these results to outdoor structures -- in particular, poorly prepared structures -- is very difficult.

Initial exposure and climatic conditions can play an important role in the protection afforded by a galvanize coat (Stanners, 1972). When a galvanized structure is exposed to humidity and then dry sulfur dioxide, the corrosion rate will be lower than if initial exposure is to dry sulfur dioxide followed by humidity. Because the order of events is important in predicting the useful life in a given environment, the average values of pollution[2] and meteorological conditions are not sufficient to predict corrosion behaviour (Stanners, 1972).

Corrosion rates will also differ among different alloys of the same base metal. For example, the following table compares the corrosion rates of two copper alloys at the same test sites under the same conditions derived from 20-year exposure tests (American Society for Metals, 1979).

Copper Alloy	**New York, NY**	**Altoona, Pa**
C11000	1.38 um/yr	1.40 um/yr
C52100	2.54 um/yr	2.24 um/yr

Corrosion rates for these two alloys differ by 85% and 60% at the two sites.

5.3.3 Atmospheric Exposure Conditions

Atmospheric exposure conditions, such as temperature, structure temperature[3], wetness (including humidity), and deposition velocity affect corrosion and, consequently, acid deposition dose-response relationships. Low corrosion rates can be expected in cold, dry atmospheric conditions. Corrosion rates generally increase with temperature and wetness.

The length of time of wetness of structures can be estimated from climatic data for particular regions (e.g., for Ottawa the estimated wet-time is 29%). However, it is possible for changes in time of wetness to have unexpected effects. Less precipitation or time of wetness can actually increase the corrosion rate because there is less washing action and removal of pollutants.

Generalizing average atmospheric conditions for one location to the Province of Ontario could be misleading, especially when the variety in weather patterns is taken into account. For example, the 1980 model uses an interaction value for zinc based on Ottawa's average humidity of 80% for all regions in the province. If, however, average humidity at another location is only 60%, the 1980 interaction value for that location would be overestimated three-fold.

5.3.4 Nature of Impacts

The nature of the impacts of acid deposition varies by material, and not all impacts will be captured in estimates for surface corrosion rates. For some materials, secondary effects such as increased internal stresses can also play an important role in the overall dose-response relationships. For example, natural stone structures of sedimentary rocks, such as limestone and sandstone, contain calcium carbonate (commonly known as calcite) as a main constituent. When calcium carbonate is exposed to sulfuric acid, calcium sulfate (gypsum) is formed. The first step of calcite to anhydrite results in a 28% volume increase. The second step of anhydrite to gypsum results in a further 19% volume increase (World Congress on Air Quality, 1983). The severe internal stresses associated with such large volume changes often result in cracking and fracturing of the stone.

This cracking leads to further penetration of acid solutions into the pore structures of the stone to which naturally porous stones, such as sandstone, are very prone. The product of the chemical reaction, gypsum, has a soluability approximately 30 times that of the original constituent, calcite (Martin, 1981). The leaching of gypsum may further weaken the structure of the stone. In sandstone, where calcite is the bonding agent between grains of quartz, the loss of calcite (as it is transformed into gypsum) weakens the structure of the stone, leaving it more susceptible to natural weathering actions.

Marble and limestone contain veins of clay minerals which generally have a high surface area to volume ratio and a high absorption capacity. Expansion of the minerals creates surface and internal pressures, and sulfate absorption creates further sites for stone decay (Gauri, undated).

In natural stones, the stability of silicate materials exposed to atmospheric agents is determined by their ionic potentials and the existence of free valence near the crystal surface. An equilibrium reaction occurs in the natural environment with oxygen and water. The introduction of acidic solutions disturbs the equilibrium and promotes degradation (Jenny, 1950).

Degradation of man-made stone (e.g., concrete, brick) can also occur by the leaching of free lime by acidic solutions and the reaction between soluable components of the concrete and agressive solutions (Dillon, 1973). The leaching of free lime in concrete may not be confined to the surface (Tramper, 1981) and can occur internally as a function of porosity.

Furthermore, the rate of degradation may change with time. In concrete, for example, sulfates or sulfuric acid react with the tricalcium aluminate to form calcium sulfoaluminate hydrate which results in increased internal stress levels. Initially, the concrete or mortar increases in strength. As the process continues, the concrete or mortar expands, cracks, and becomes progressively weaker (Kuenning, 1966).

For specific materials with corrosion rates which rise linearly with time (e.g., zinc; see American Society for Metals, 1979; Zinc Institute, 1971), the assumption of a corrosion rate for a specific humidity and sulfur dioxide concentration may be valid for the time period considered.

However, for other materials the corrosion rate with time is parabolic (e.g., carbon steel) and wide ranges of corrosion rates can be found in the literature for a variety of materials and in some cases even the same material in the same location (Stanners, 1972). In some environments, the initial rate of corrosion can be far higher than in future years. The high (early) rate is due to the formation of initial corrosion products which act as a diffusion barrier. As corrosion products are formed, the rate of corrosion falls. Therefore, future metal loss predictions may be greatly overestimated, if an initial corrosion rate is used. If a later corrosion rate is used, no consideration will have been given to the higher corrosion during the initial phase and metal loss calculations will be underestimated.

5.3.5 Summary

Exhibit 5.1 summarizes factors that will affect the impact of acid deposition on materials. These factors should be included when deriving acid deposition dose-response relationships. Exhibit 5.1 also indicates how values for these factors vary and, where data are available, the effect modifications of these values may have on corrosion rates. For example, considerations of surface preparation will vary by structure (i.e., structure-specific data are required) and may affect corrosion estimates by 100%.

5.3.6 Options for Calculating Materials Impacts

The prevalence of the need for structure-specific data in Exhibit 5.1 suggests that impacts of acid deposition would best be estimated using a **component approach.** The component approach considers damage to specific structures, not material categories. This approach was used by Battelle Columbus Laboratories (Fink et. al., 1971) to examine impacts of polluted atmospheres on tanks, bridges, power transformers, street lighting, outdoor metal work, chain link fences, and so on.[4]

The steps in a component evaluation approach are:

(1) Screen all structure types to determine those susceptible to damage as a result of acid deposition. Possible criteria include economic importance, susceptibility to corrosion, and extent of exposure.

(2) Collect data on the number and value of susceptible structure types.

(3) Determine physical damage (e.g., rates of corrosion) by structure type.

(4) Calculate the economic value of physical damage from the cost of replacing (portions of) the damaged structure or the cost of applying protective coatings more often.

The component approach requires intensive data collection to develop an inventory of structures in place for each structure type and to determine average values for structure-specific factors noted in Exhibit 5.1.

This data collection effort extends beyond the scope of the current modelling endeavour; however, a recent study by the Leman Group Inc. (for the National Research Council and Environment Canada) outlined a methodology for determining

EXHIBIT 5.1: FACTORS AFFECTING MATERIALS DEGRADATION

Factor	**Comment**
(a) Deposition Considerations	
Acid Deposition	Serious lack of quantitative data specific to the effects of acid deposition (i.e., sulfates and NO_x) on materials. SO_2 used as surrogate for sulfates.
Dry deposition	Little or no quantitative data specific to the effects of dry sulfates and nitrates on materials.
Area exposed	Structure-specific data required.
(b) **Material Sensitivity**	
Material quality	Structure-specific data required.
Surface preparation	Structure-specific data required. (The quality of surface preparation could half the cost of recoating.)
Initial exposure	Structure-specific data required.
Alloy	Alloy-specific dose-response relationships required. (Corrosion rates for different alloys in the same polluted atmosphere may vary by as much as 85%.)
(c) **Atmospheric Exposure Conditions**	Location and season-specific data required. (Corrosion rates may differ three-fold.)
(d) **Nature of Impacts**	Dose-response relationships need to account for internal structural impacts, as well as surface corrosion. Susceptibility of internal impacts requires material-specific data.
Non-linear impacts	Material/structure age-specific data required.

and measuring the distribution of materials at risk in urban environments. The methodology consists of "surveying selected real estate properties for their entire contents and measuring and calculating the distribution of materials' surfaces exposed to acidic dry and wet deposition" (Leman, 1986). Survey properties are selected randomly from four categories: low-rise residential, high-rise residential, industrial, and commercial/institutional. The methodology produces estimates of materials at risk by category, by type of material and on a per capita basis (Leman, 1986).

The Leman methodology has been tested on a demonstration basis only. The report recommends that a Pilot Study be undertaken. Should the results of a pilot study be encouraging, this methodology may provide an important step toward the component approach.

The **material category approach** estimates impacts by type of material, regardless of use. Unlike the component approach, the material category approach abstracts from structure-specific variability and, in so doing, introduces errors into the damage estimates. To avoid additional, potentially serious errors, corrosion formulae used in the material category approach should, to the extent possible, be specified by:

- metal alloy;
- wet and dry deposition;
- atmospheric conditions, such as humidity, wet times, temperature; and
- susceptibility to acid-induced internal stresses.

5.4 Recommended Revisions to Materials Component

The materials component in the 1980 model falls short of the material category approach described above and has embedded in it errors arising from:

- generalization over metal alloys, atmospheric conditions, and susceptibility to internal stresses;

- exclusion of dry deposition effects;
- corrosion rates used for zinc, aluminum, and copper;
- exclusion of steel as a material at risk; and
- generalization of impacts on alkyd to all paint types.

However, the literature review undertaken for this study clearly indicates that quantitative information required to amend these shortcomings is not currently available: corrosion rates are generalized over many factors and rates specific to acid deposition (instead of SO_2) are not available.

It is the consultant's opinion that, even using the most recent information available from the literature review, any estimates of material damage attributable to acid deposition may err by up to an order of magnitude. One option available to MOE is to postpone estimation of materials effects, to continue to monitor the scientific literature for more appropriate corrosion formulae, sponsor field studies for Ontario, and to follow developments in methodologies for estimating materials at risk (e.g., Leman, 1985).

Recommendation 1: MOE should proceed with the 1980 material category approach using available corrosion formulae for dose-response relationships. However, damage estimates and conclusions should be couched in appropriate terms of uncertainty. MOE should also monitor and, to the extent possible, contribute to the development of methodologies for estimating materials at risk and Ontario-specific corrosion formulae.

5.4.1 Physical Effects

Specific revisions to the 1980 corrosion formulae are discussed below.

In the 1980 model, deposition of sulfates is converted to an 'equivalent' concentration of sulfur dioxide to allow the use of available SO_2/corrosion formulae: "An 'equivalent' concentration of SO_2 represents the concentration of SO_2 which would produce an annual deposition (as Sulphur) at a material surface equivalent to the deposition of sulphur (as Sulphate) by acid precipitation" (Victor and Burrell, 1982).

The computer code for the 1980 model in fact relates hydrogen ion concentrations to SO_2 using a parameter value of 0.1143. As noted above (see Section 5.3.1), the appropriate parameter value may vary by time and location. Any single value should, therefore, be considered a rough approximation.

Recommendation 2: It is recommended that the model relate sulfate (not H^+) to SO_2 and that the user specify the conversion factor. If desired, a default value based on equivalent atomic weights can be input.

As discussed above, the effects of dry deposition may be similar, if not more serious than those of wet deposition and should, therefore, be taken into account in the material damage estimates. In the 1980 model, the interaction value is reduced to 40% of its original level. This is done to reflect the fact that sulfates in acid rain (i.e., wet deposition) are likely to be in contact with materials for shorter time than airborne pollutants (i.e., dry deposition) (Victor and Burrell, 1982). To include the effects of dry deposition, this adjustment should be deleted.

Recommendation 3: Include the effects of dry deposition by eliminating adjustments to interaction values.

Corrosion rates are affected synergistically by SO_2 and temperature, time of wetness, etc. However, it is not advisable to attempt to estimate corrosion on a seasonal basis. Reported data and formulae are invariably in the form of mils per year (mpy) or micrometres per year (um/yr) which gives the average for the year from which seasonal interaction values cannot be derived.

No new formulae for the effects of acid deposition on marble, concrete, and aluminum were identified.

Recommendation 4: The 1980 corrosion formulae for concrete, marble and aluminum should be maintained because no new information is available.

No new data or formulae were identified for paints. In particular, no information is available to differentiate the effects of acid deposition (or SO_2 as a surrogate) on different types of paints. The 1980 model applies the corrosion rate for alkyds to all paint types, a generalization which may introduce more serious errors than generalizing across different alloys of one base metal.

The reasoning upon which the 1980 interaction value is based also introduces errors. The 1980 model uses a corrosion rate of 2 um/year with SO_2 levels of 60 ug/m^3 to determine repainting time. In fact, repainting is determined by both corrosion and aesthetics. Paint breaks down in local patches and surfaces are generally repainted when local patches account for 20% or more of the surface, not necessarily when the entire painted surface has disintegrated -- as assumed in the 1980 model.

In summary, it should be recognized that estimates for damage to paints are particularly subject to error because the methodology assumes that one corrosion rate is applicable for all paint types and that repainting occurs after total surface corrosion; furthermore, they do not consider the quality of surface preparation. Lack of better information, however, precludes any improvements to the 1980 interaction value.

Information collected through the literature review and interviews did provide an opportunity to evaluate the list of materials included in the 1980 model and to compare corrosion formulae for zinc. The following recommendations are based on this information.

Although it has been reported that nickel and nickel-plated products corrode more quickly in high than in low SO_2 atmospheres (Hendriksen and Haagenrud, 1981), the corrosion rate is significantly lower than for other metals. Overall, nickel has shown "excellent resistance to corrosion in rural, industrial and marine atmospheres" (American Society of Metals, 1979).

Recommendation 5: It is recommended that nickel be excluded from the model because data indicate it is not significantly affected by acid deposition.

The 1980 model does not include steel as a material at risk to acid deposition degradation. Although stainless steels perform well in polluted environments (Hendriksen and Haagenrud, 1981), both carbon and weathering steels are sensitive to pollutants, including acid deposition and high levels of SO_2. These two types of steel are widely used and should be included in the MOE model. The effects of acid deposition on carbon and weathering steels are described below.

a) Carbon Steel

Carbon steels have low corrosion resistance due to the limited protection afforded by the surface films formed on exposure to the environment. In non-polluted atmospheres, rust films on carbon steel are composed of two layers (Mattsson, 1982): the layer adjacent to the steel is a dense composite of FeOOH with some crystalline Fe3O4; the outer layer consists of a loose mixture of alpha FeOOH and gamma FeOOH. Although these corrosion products offer some protection, they are susceptible to acid dissolution and diffusion of pollutants. In a study in which corrosion rates of carbon steel in eight major cities were investigated

(Haynie, 1974), the parabolic relationship between corrosion rate and time was shown to increase with increasing sulfur dioxide concentration.

Corrosion rates for carbon steel vary from location to location. The following table (Krause, 1975) gives an idea of rates to be expected:

Location	**Mean Corrosion Rate (um/yr)**
Rural	4 to 65
Urban	23 to 71
Industrial	26 to 175
Marine	26 to 104

The corrosion rate of carbon steel has been related to the time of wetness, surface temperature, sulfur dioxide concentration, and chloride count (Stanners, 1972). Of interest is the apparent effect of temperature. Studies in Moscow (Stanners, 1972) show corrosion rates are higher at low temperatures -- which is contrary to most processes. The explanation relates to the increased sulfur dioxide concentration in the atmosphere in winter months (Stanners, 1972). More use of heating fuels and increased loads on hydro generating facilities produce more atmospheric pollutants.

Corrosion by polluted atmospheres can involve a variety of reactions:

- Rust films formed on carbon steel can be less protective due to the incorporation of pollutants in the film (Nriagu, 1978).

- Rust can actually catalyse the reaction of sulfur dioxide to sulfate. (Barton, et. al., 1972)

- The incorporation of particulate matter in the surface film can increase hygroscopic properties, allowing for increased water retention, increased acid content, greater permeability, and longer surface wetness time.

- Surface films are susceptible to increased soluability in acidic environments and corrosion is related to the diffusion of active agents through the film.

Of particular note is that low concentrations of some gaseous hydrocarbons in polluted environments can inhibit the corrosion of carbon steel (Arshadi, et. al. 1983). Isobutane in low concentrations reduces the corrosion rate of carbon steel, but in high concentrations causes the rate to increase.

Coating carbon steel structures after corrosion has occured can be difficult. For good adhesion, the surface must be clean. Dry blasting does not always remove chemical salt residues (e.g., chlorides, sulfates) and coating over the residues leads to breakdown of the coating (Calabrese and Allan, 1978) . Wet blasting has been found to be effective in removing a variety of chemical salt residues, but is expensive. In practice, carbon steel structures are cleaned as far as economics and climatic conditions allow. Because salt residues are often left on the steel, maintenance coatings occur frequently.

b) Weathering Steel

Weathering steels are low alloy carbon steels containing small additions of copper, nickel, chromium, phosphorous, silicon, and manganese. These steels are now used on many structures as a means of circumventing the costs of coating carbon steel and still maintaining structural integrity. The effect of atmospheric pollutants on these types of steels is very important as no coating is applied as a primary barrier between the metal and the atmospheric environment. In rural and some urban areas, the initial surface corrosion that occurs would provide a more protective film than on plain carbon steels. In polluted atmospheric environments, however, the lack of a primary barrier causes higher rates for weathering steels.

The following corrosion rates are from controlled environment testing (Haynie, et. al., 1975), and can be used for comparative purposes:

Atmosphere	**Average Corrosion Rate um/yr**
Clean Air	1 to 86
Polluted	84 to 762

Factors contributing to the differences in these rates are the sulfur dioxide level, relative humidity, and temperature.

The effectiveness of weathering steels against pollutants is based on the protective characteristics of the rust layer formed during initial exposure. Where the sulfur dioxide level is high and wet conditions often prevail, the corrosion rates of weathering steels can be the same as for carbon steel (Mattsson, 1982). In these cases, the atmospheric pollutants neutralize the benefits of using weathering steel and other protective measures should be used.

Recommendation 6: It is recommended that carbon and weathering steels be added to the set of materials for which damage is estimated.

Corrosion formulae relevant to steel are presented in Exhibit 5.2. These formulae were reviewed for appropriateness to the MOE model. All formulae use SO_2 as a proxy for sulfate deposition. As noted above, this approximation can, under some circumstances, be very rough. However, no formulae relating corrosion to sulfate are available. Furthermore, available corrosion formulae are not specified for carbon and weathering steels.

EXHIBIT 5.2: CORROSION FORMULAE FOR STEEL[a]

FORMULA NO.	CORROSION FORMULA	REFERENCE
(i)	$Y = 9.5 + (0.0206\ SO2)t$ where Y is thickness loss in um where SO2 is annual average SO2 concentration in ug/m^3 where t is time of exposure in years [see Note b]	Stankunas, et. al (1982) reporting Upham (1967)
(ii)	$Y = 9.013\ e^{0.00161\ SO2}\ (4.768t)^{0.7512-0.00582(O3)}$ where O3 is the annual average concentration of O3 in ug/m^3 where other parameters as in (i)	Stankunas, et. al (1982) reporting Haynie & Upham (1971) carbon steel
(iii)	$K = 1.54\ SO2 + 2.34\ DPREC + 0.05H+ - 15.2$ where K is monthly corrosion rate (g/m^2) where SO2 is concentration of SO2 in air (ug/m^3) where DPREC is days with precipitation where H+ is concentration of strong acid in precipitation (u-equiv.H+)	Sherwood (1984) reporting Birbenes et. al. (1982)
(iv) Tokyo (1 month)	$Q = (-1.63 + 0.028H + 0.066R + 0.083S1)t$ where Q is corrosion (um) where H is relative humidity (%) where R is rainfall (mm per day) where S1 is SO2 collected on PbO2 (mg/dm^2 per day) where t is elapsed time (days)	Stanners (1972) reporting Oma, et. al. (1965)
(v) Moscow (2 months, 1 year)	$Q = (0.062 + 0.015T + 0.025S2 + 0.0031T*S2)t*W*P*a*b$ where Q is corrosion (um) where T is temperature (^oC) where S2 is SO2 in moisture film (mg per m^3) where t is time of exposure in years where W is time of wetness/elapsed time where P is rust coefficient (see Golubur & Kadyrov, 1967) where a is aspect coefficient (see Golubur & Kadyrov, 1967) where b is shelter coefficient (see Golubur & Kadyrov, 1967)	Stanners (1972) reporting Golubev & Kadyrov (1967)
(vi) Sheffield (1 year)	$Q = (0.035 + 0.70S)t$ where Q is corrosion (um) where S is SO2 in air (mg/um^3) where t is elapsed time	Stanners (1972) reporting Tomashov (1966)

... continued

EXHIBIT 5.2: CORROSION FORMULAE FOR STEEL[a] continued

FORMULA NO.	CORROSION FORMULA	REFERENCE
(vii) Ottawa (1 month)	$Q = (0.068 + 1.16Sw + 0.0038Tw - 0.0005Tw^2$ $+ 0.24\ W + 0.016W{*}Tw)t$ where Q is corrosion (um) where Sw & Tw relate to wet-time measurements [see Note c] where W is time of wetness/elapsed time where t is time of exposure in years	Stanners (1972) reporting Guttman & Sereda (1968)
(viii) Ottawa (1-18 months)	$Q = 2.07 + 39.1Sw + 0.052Tw - 0.018Tw^2$ $+ 0.34t{*}W - 0.0006t^2{*}W^2$ where parameters as in (vii)	Stanners (1972) reporting Guttman & Sereda (1968)
(ix) Ottawa (1-18 months)	$Q = 0.63\ (Sw + 1.78)(t{*}W)^{0.706}$ where parameters as in (vii)	Stanners (1972) reporting Guttman & Sereda (1968)

Notes:

a. Equations below were not specified by steel alloy in the references. As discussed in the text, alloying metals can effect variations in corrosion rates. Dose-response relationships are only available for SO2 as a proxy for the sulfate component of acid deposition.

b. Upham studied the corrosion of mild steel in two US areas (St. Louis and Chicago), and reported several damage functions for the corrosion rate as a function of the sulfation rate or sulfur dioxide concentration. Different damage functions were reported for each urban area, for each SO2 concentration averaging time with each length of exposure. Stankunas, et. al. (1982) selected this linear function for analysis.

c. Wet-time measurements are taken during times of high humidity or during precipitation. These measurements can vary from those taken during "dry" times. Sw is the SO2 concentration in the air in ug/m^3 and Tw is the ambient air temperature in degrees Celsius.

Numerous formulae ((ii), (iii), (iv) and (v)) were excluded from consideration because they require data which are not readily available (i.e., rust, aspect and shelter coefficients); nor were they supported empirically (i.e., corrosion rates calculated using these equations did not correlate with actual field data).

For other formulae, data are available but comparison with Ontario experience (i.e., actual corrosion rates for steel in Ottawa; see Zinc Institute, 1971, pp. 48-49) cast some doubt on their validity. For example:

- formulae (i) and (vi) yield low corrosion estimates; and
- formula (viii) changes very little with SO_2 in the range of 20 to 80 ug/m^3, nor does the rate of change with temperature appear correct.

Formulae (vii) and (ix) provide reasonable estimates compared with observed Ontario experience in separate ranges of SO_2 levels. Formula (vii), which is based on 1 month data for Ottawa yields the best available corrosion estimates for SO_2 levels of 80 ug/m^3 or greater. Formula (ix), which is based on 1-18 month data for Ottawa yields the best estimates when SO_2 levels are 40 um/m^3 or less.

Recommendation 7: It is recommended that both of the following formulae be used in the revised model to estimate acid deposition effects on steel:

(a) $Q = (0.068 + 1.16Sw + 0.0038\ Tw - 0.0005\ Tw^2 + 0.24\ W + 0.016\ W*Tw)t$

(b) $Q = 0.63\ (Sw + 1.78)t*W^{0.706}$

where Q = corrosion (um)

Sw and Tw are wet-time measurements for SO_2 concentration and temperature

W = time of wetness/elapsed time

t = time of exposure in years.

[Equations (vii) and (ix), respectively, in Exhibit 5.2 from Guttman and Sereda (1968) in Stanners (1972).]

Where SO_2 deposition is 40 ug/m^3 or less, damage estimates should be based on the first equation; where deposition is 80 ug/m^3 greater, the second equation should be used; and a straight average of estimates from the two equations should apply for intermediate levels of SO_2 deposition.

As described in Section 5.2, the 1980 model uses interaction values calculated from corrosion formulae. The interaction values associated with equations (a) and (b) are $(1.84 + 4.45SO_2) \times 10^{-2}$ and $(3.9 + 2.2SO_2) \times 10^{-3}$, respectively.[5] These new values should be input to the computer code to replace the 1980 values.

The final suggested amendment to the 1980 model concerns impacts on zinc. Corrosion estimates using the 1980 model's data (formula (iv) in Exhibit 5.3) were compared with observed corrosion rates. The 1980 estimate was significantly lower than observed rates and gave an unrealistic corrosion rate (of zero) when SO_2 levels were set at zero.

Formulae (i) and (iii) in Exhibit 5.3 yield corrosion estimates much closer to observed values. The two formulae follow each other fairly well except at very high SO_2 levels where the accuracy of the third formula becomes questionable.

The zinc formula (ii) in Exhibit 5.3 is very dependent on temperature. At lower (higher) temperatures, corrosion rates appear unrealistically low (high).

Recommendation 8: After reviewing available corrosion formulae, the 1980 formula on which the interaction value for zinc is based be replaced with:

$$Y = (2.4 + 0.045\ SO_2)tw$$

EXHIBIT 5.3: CORROSION FORMULAE FOR ZINC

FORMULA NO.	CORROSION FORMULA	REFERENCE
(i)	$Y = (2.4 + 0.045\ SO2)tw$ where Y is thickness loss in um where tw is time of wetness in years where SO2 is annual average SO2 concentration in ug/m^3	Stankunas, et.al. (1982) reporting Haynie, chain link fencing (1980)
(ii)	$Y = [0.187\ SO2 + \exp[41.85 - (23240/R*T)]tw$ where R is the gas constant (1.9872 cal/g-mole) where T is the temperature in ^{o}K where exp (x) refers to mathematical term "e to the exponent x" where e = 2.71828 where other parameters as in (i)	Stankunas, et. al (1982) reporting Haynie (1976)
(iii)	$Y = 0.02468\ tw\ 0.8152\ (SO2 + 75.69)$ where parameters as in (i)	Sankunas, et.al. (1982) reporting Guttman (1968)
(iv)	$Y = 0.001028\ (H - 48.8)S$ where Y is thickness loss in um where H is average relative humidity (%) where S is annual average SO2 concentration in ug/um^3	Haynie & Upman (1970) in Victor & Burrell (1982)

where Y = thickness of loss in um

tw = time of wetness in years

SO_2 = annual average SO_2 concentration in ug/m^3

[Haynie, 1980 in Stankunas et. al, 1982]

The interaction value associated with this (revised) formula is $(371.2 + 6.96\ SO_2) \times 10^{-5}$ for wet deposition and $(92.8 + 1.73\ SO_2) \times 10^{-4}$ for wet and dry deposition.[6]

5.4.2 Economic Valuation

Physical effects of acid deposition on materials have four different economic impacts:

- increased maintenance requirements;
- increased replacement requirements;
- decreased utility (e.g., soiling and visual aesthetics); and
- replacement of original material with more costly substitutes.

Conceptually, the economic valuation methodology should incorporate each type of impact. The methodology should calculate the present value difference in the cost of using a material with and without acid deposition, including a factor for amenity costs (e.g., unsightliness). The methodology should take into account differences in uses for each material. Furthermore, the operative economic impact (i.e., the impact which defines human response) will differ by material and end use, as well as by the nature and extent of physical effects of acid deposition. For example, soiling of painted services may not be important in industrial environments, as it is in commercial environments. The paint's ability to protect industrial equipment may, however, necessitate more frequent repainting (replacement) or substitution for alternate, more costly protection.

These methodological ingredients again suggest a component approach to estimating impacts of acid deposition on materials; by identifying individual structures and, therefore, end uses for individual materials, expected economic life, operative economic impact, exposure factors, etc. can be more accurately determined. As discussed, however, the data collection effort required to support the component approach is outside the scope of the current modelling effort.

The valuation methodology used in the 1980 model, derived from Salmon (1970), calculates:

$$D_r = C \times L \times V \times E \times I_r \times P_r$$

Where:

D_r = Annual damages in region r (1980$)
C = Consumption of material in Ontario in 1979 (1980$)
L = Estimated economic life of the material
V = Value added factor to reflect material's value in place
E = Exposure factor (%)
P_r = (Population in region r)/(Ontario population)
I_r = Interaction Value

The term (C x L x V) yields the total value of the stock of material in place in the province. Applying a population factor (P_r) distributes this stock by region. The value of the regional stock which is exposed to acid deposition (i.e., the value of materials at risk) is calculated using the exposure factor (E) which is defined by material. Finally, the interaction value (I_r), which is defined by SO_2 (as a proxy for acid deposition) levels and, hence, by region, yields the "average fractional loss of useful life per year" (Victor and Burrell 1982). The total economic impact of acid deposition on buildings and structures in Ontario is calculated as the sum of damages over all regions and all materials examined.

Of the four economic impacts of acid deposition noted above, the 1980 model addresses increased maintenance and replacement costs only. Although a partial analysis, the following considerations suggest that the approach is reasonable. First, dose-response relationships for soiling are lacking. Second, the amount people are willing to spend on higher cleaning bills may fall short of that necessary to counteract increased soiling; people may accept soiled surfaces. In these cases, the economic cost of acid deposition cannot be directly linked with changes in the rate of soiling. Thirdly, detailed material and use (structure) data is required to identify where substitution of materials would be appropriate and material performance specifications are needed to identify the next best alternative material for each use.

The methodological framework used in the 1980 model is essentially sound. It takes into account the value of materials at risk, accounting for exposure and value added factors and regionalizes estimates both by the volume of materials in place (using population ratios) and (a proxy for) acid deposition levels. Finally, the sophistication and data requirements of the 1980 economic valuation methodology are commensurate with the availability and reliability of scientific data and knowledge.

Recommendation 9: The current structure of the economic valuation methodology should be maintained: however, it should be noted that the exclusion of soiling and substitution impacts will **ceteris paribus** underestimate the economic cost of materials damage.

Victor and Burrell (1982) notes several limitations with the specifics of the economic valuation of impacts. The recommendations documented below address some of these limitations.

First, consumption data should be updated. Consumption rather than production data should be used where possible as they exclude inventories and more closely reflect materials in use. Consumption data should exclude exports from and include imports to Ontario. The use of a single year estimate for consumption could introduce errors to the calculation if the base year represents unusual economic conditions. Instead, consumption data should be averaged over a number of years (e.g., 1978-1984).

Recommendation 10: Consumption data should be updated. It should be based on consumption (versus production) data when possible and averaged over a number of years.

Victor and Burrell (1982) notes that current sales will, "only under special circumstances (e.g., a steady state economy) ... accurately capture the desired consumption quantity". The approach used in the 1980 model implicitly assumes that the inventory of materials at risk remains constant over time. In other models in this study (i.e., agriculture and forestry), an attempt has been made to introduce dynamic and consistent forecasts of resources at risk. The forecasting task is more difficult for materials because consumption in any year accounts for both replacement and additions to the material stock.

On an aggregate level, however, one can expect some growth in the building stock (i.e., in the inventory of materials at risk). Depending on the material and its end use, growth may be related to change in GNP, investment, population, or the rate of urbanization. Forecasts of materials consumption should incorporate a growth factor equal to either the population growth rate or the expected growth rate for GNP.

Although the population growth may in some years underestimate the growth in materials stock, it yields a steadier expansion and avoids problems associated with negative growth (recessionary) years.

Recommendation 11: It is recommended that the stock of materials at risk grow at the population growth rate.

Victor and Burrell (1982) question Salmon's (1970) premise that a decrease in a material's physical life will be fully felt as a reduction in its economic life. For example, a variety of factors may determine that a building needs to be repainted once every four years. Acid deposition related corrosion may not accelerate deterioration to the extent that this standard maintenance would be changed.

Although a valid concern, overcoming this limitation would require information on specific end uses, materials, and maintenance decisions. This micro-level of decision making is not possible within the budget for the MOE Model Review nor is it practical given the overall error inherent in the physical damage estimates. The assumption that a change in physical life will be fully felt as a change in economic life should, therefore, be maintained but it should be recognized that this assumption may overestimate the value of economic impacts.

The 1980 model uses economic life values drawn directly from Salmon (1970). These estimates are in turn based on US Treasury (Internal Revenue Service) rules and guidelines on depreciation. The values used, therefore, are more likely to represent accounting or book life rather than economic or service life. Limited information on hand suggests there are discrepancies between different data sources - discrepancies which become multiplicative in the calculation of economic impacts. For example, the OECD (1981) assumes the service life of galvanized materials to be about 25 years, as opposed to the 36 years assumed by Salmon. Corresponding values for paint are 10 years and four years. Values for economic life may be updated and adapted to the Canadian (Ontario) situation by verifying Salmon's assumptions with material experts in Canada.

Recommendation 12: It is recommended that the economic life values used from Salmon (1970) be verified with Canadian materials experts.

Exposure factors used in the 1980 model are adopted directly from Salmon (1970). Neither reference nor methodology for calculation of these exposure factors were provided in the original report, so it is difficult to evaluate their validity. The situation is similar for assumptions regarding the thickness of materials. Victor and Burrell (1982) suggest that "it would be useful to attempt to establish, perhaps through sample investigation of the built environment, some empirically derived exposure factor estimate" for Ontario.

Although a commendable course of action, such empirically derived exposure factors are not likely to be available in the short-term. In the long-term, budget and time may be allocated to develop such estimates based on a survey methodology such as that recommended by the Leman Group Inc (1985). In the near future, some effort may be spent on verifying the 1980 exposure factors through interviews with material experts.

Recomendation 13: Until empirically-derived exposure factors for Ontario can be derived, it is recommended that the 1980 exposure factors be reviewed and verified by material experts.

The 1980 model regionalizes the stock of materials at risk based on population ratios.

Recommendation 14: Population data and population ratios should be updated to the most recent available information.

Victor and Burrell (1982) point out that Salmon's labour or value-added factors do not consider the value of service rendered by the materials. The authors discuss the failure of small nickel plated computer components which could have economic costs many orders of magnitude greater than their market price. The "value in service" cost of acid deposition may be calculated as:

Change in number of failures x cost per failure

Calculation of this cost would require the following steps:

- develop an inventory of possible failure incidences, including the degree of exposure to acid deposition;
- screen the inventory to identify important failure incidences, based on criteria such as likelihood of failure, population of possible incidences, magnitude of failure (cost, disruption), possible safeguards;
- on a case study basis, identify the nature and cost of failure (including the cost of downtime, repair or replacement, value of loss output);
- estimate the current level of failure incidences;
- determine effective acid deposition including:
  - the degree of exposure to acid deposition
  - the extent and effectiveness of safeguards against failure
  - changes in behaviour (e.g., more frequent maintenance, more extensive safeguards and warning systems).
- calculate the new level of failure incidents related to a given rate of corrosion or acid deposition;
- extrapolate case study results to provincial totals.

Although feasible, we suggest in service valuation of the economic impacts of acid deposition not be incorporated in the MOE model. Given the overview nature of the model, in service valuation requires very costly and time consuming data collection efforts, and even with such an initiative, would produce only partial results.

Furthermore, in service valuation may not have a significant effect on overall economic impacts of acid deposition. For example, significant safeguards, warning systems, and operating contingencies are likely to accompany uses of any material whose failure would result in significant mechanical or economic damage. In these circumstances, the economic cost of acid deposition is not the cost associated with failure but that associated with using or changing safeguards.

Recommendation 15: It is recommended that in-service valuation not be incorporated in the calculation of economic impacts of materials damaged.

5.5 Water Supply Systems

The level of acidity (pH) of water can have three possible impacts on water supply systems. First, low pH levels (e.g., below 6.5) increase reaction of water with piping system materials which releases small quantities of chemicals harmful to human health (e.g., lead, copper, asbestos). Second, corrosion rates may increase, thereby shortening the useful life of the water distribution system. Both these impacts were noted in Victor and Burrell (1982).

The third impact may be beneficial: at high pH (of about 9), calcium carbonate comes out of solution and tends to coat the internal surfaces of the pipes. This coating is referred to as scaling. In areas of high natural pH, acid deposition may acidify natural water supplies and mitigate the scaling problem, thereby reducing internal pipe cleaning and pumping costs.

The economic implications of acid deposition on water supply systems depend on how or whether water would be treated to offset the effects of acid deposition.

5.5.1 Municipal Water Supply Systems

Municipal water supply systems are designed to deliver potable, acceptable (e.g., in terms of taste) water to the public. In many municipalities, surface water requires treatment before it is distributed. Typically, the intake or "raw" water is disinfected by cholorination, undesirable chemicals or particulates are removed by adding a coagulant (a process called hydrolysis), and the water is pH-adjusted to reduce corrosive effects on pipes (Gary Martin, Drinking Water Section, MOE, personal communication).[7]

In the chlorination process, either gaseous chlorine is injected into the water flow, or sodium hypochlorite (NaHOCl) is added. These disinfection methods are more efficient at lower pH levels. Where new raw water pH is not low enough, disinfection is coordinated with other parts of the treatment process which lower pH (e.g., hydrolysis).

Hydrolysis of water involves adding a coagulant to remove undesirable particulates. Alum (Al2 (SO4)3), ferric chloride (FeCl3) or polyaluminum chloride are used as coagulants, but alum is most common. These chemicals are most effective when the pH of the water lies within a specific range. While not exact, the following ranges of pH are best for these coagulants:

Coagulant	**Preferred pH Range**
Fe Cl3	5.5-7.0 or 9.0-11.0
Al2 (SO4)3	5.5-6.5
polyal. chloride	6.0-8.0

If intake water pH is below the preferred range, alkaline chemicals are added. In general, high pH intake water is not problematic as the three coagulants cover the full range of likely pH levels. The addition of coagulants sometimes lowers water pH.

The final process for treatment sytems adjusts the pH of the water before it enters the distribution system. As outlined above, low pH tends to corrode pipes, while high pH levels cause mineral salts (i.e., calcium carbonate) to coat and constrict pipes. Because the addition of coagulants sometimes reduces pH, water pH may have to be raised to acceptable levels. The chemicals used for this adjustment are soda ash ($Na2CO3$), sodium bicarbonate ($NaHCO3$) or lime hydrate ($Ca(OH)2$). Soda ash is the most common chemical used. An acceptable range for treated water is $6.5 < pH < 8.5$, with a typical level of 7.5 (A. Vajdic, MOE, personal communication).8

Acid deposition, by lowering the pH of intake water, can affect the cost of treatment at two points: it may necessitate the addition of alkaline to raise pH to ensure coagulants work effectively (i.e., prior to hydrolysis); and it may increase the amount of chemicals required to stabilize pH before water is released into the distribution system.

The economic impact of acid deposition on water supply systems is the difference in treatment costs with and without acid deposition. This difference is determined by the difference in pH of intake water with and without deposition. If, in the absence of acid deposition, intake water at System A has a pH of 6.0, no alkaline need be added prior to hydrolysis (i.e., pH 6.0 is within the preferred range for all three coagulants). The cost of treatment is:

- the cost of adjusting pH to offset the effects of the coagulant (i.e., bringing pH back to pH of 6.0 after hydrolysis); plus
- plus the cost of raising pH from 6.0 to an acceptable 7.5 before releasing water into the distribution system.

With acid deposition, intake water pH may fall to 5.0. The cost of teatment is then:

- the cost of raising pH from 5.0 to 6.0 (i.e., to within an acceptable range for hydrolysis); plus

- the cost of adjusting pH to offset the effects of the coagulant (i.e., bringing pH back to 6.0 after hydrolysis); plus
- the cost of raising pH from 6.0 to an acceptable 7.5 before releasing water into the distribution system.

In this example, the difference in the cost of treating water with and without acid deposition is the cost of raising water pH from 5.0 to 6.0. In general, the economic impact is the cost of raising pH of water with acid deposition to its original level (i.e., its level in the absence of acid deposition).

Water treatment costs include the costs of chemicals, labour and other items, such as equipment, maintenance (Victor & Burrell, 1982). Incremental costs associated with lower intake water pH, however, are almost entirely chemical: there are little or no measurable additional labour or other costs (John Toth, MOE, personal communication).

Recommendation 16: It is recommended that the economic impact of acid deposition on water supply systems be calculated as the incremental chemical costs of raising intake water pH to its original (without acid deposition) level.

Incremental chemical requirements can be calculated from an estimate of the change in intake water pH due to acid deposition and the relationship between pH and chemical additives.

The relationship between acid deposition and intake water pH is not well understood, especially for systems drawing from groundwater sources. Some treatment plant operators do believe that their use of pH balancing chemicals has increased over the years, but there is still a lack of statistical evidence relating changes in acid deposition to water pH. Samples taken at Fort Frances, for example, showed no correlation between acid snow and ice melt and intake water pH (Gary Martin, Drinking Water Section, MOE, personal communication).[9]

In the absence of suitable data, the MOE model can, at this time, only crudely calculate changes in intake water pH from changes in the pH of wet deposition. This method is far from satisfactory as it does not account for:

- buffering capacity of watershed geology;
- the role of carbon dioxide in lowering groundwater pH levels (Sibul and Reynolds, 1982);
- dry deposition.

Recommendation 17: To calculate economic impacts on municipal water supply systems, it is recommended that changes in intake pH for municipal water supply systems be calculated from changes in the pH of wet deposition. In the absence of other information, the changes can be assumed to be proportional (i.e., if the pH of wet deposition falls by x%, then intake pH for municipal water supply systems falls by x%). The consultant emphasizes that this relationship should be reviewed and modified as data and analysis become available.

The relationship between pH and chemical additives can be broken into two parts: the effect of chemical additives on alkalinity and the relationship between alkalinity and pH. The effect of chemical additives on alkalinity depends on the chemical used, as follows:

Chemical	Increase in alkalinity per mg/l added
$NaHCO_3$ (Sodium bicarbonate)	0.94 mg/l
Na_2CO_3 (Soda ash)	1.26 mg/l
$Ca(OH)_2$ (Lime hydrate)	0.60 mg/l

The relationship between alkalinity and pH is not direct. pH is the natural log of hydrogen ion (H^+) concentration. Alkalinity covers a variety of factors such as OH, CO_3, etc. The relationship depends on other properties (e.g., salt, minerals) in the water, which vary throughout the province. Toronto water, for example, has a pH of about 8. If triple distilled water (i.e., pH 4.5 and zero alkalinity) were combined with Toronto water in equal parts, one would expect a pH of about 6.25. In fact, the pH would be closer to 7.0 because the high mineral content of Toronto water absorbs some of the H^+ ions during the mixing.

Because water chemistry varies, no single relationship between alkalinity (or chemical additives) and pH can be used province-wide (V. Westlake, Monenco Ltd. and G. Martin, MOE, personal communications). Instead, relationships must be specified for each water treatment system. The Drinking Water Section of MOE has a computer model which calculates additive requirements for various treatment systems. Simulation runs could produce an (approximate) relationship for each system, although this approach should be verified in further discussions with the model's architects.

Once the volume of incremental chemical requirements is determined, the associated annual cost can be calculated as:

$$\underset{(\$/\text{year})}{\text{incremental cost}} = \underset{(\text{mg/litre})}{\text{chemical req.}} * \underset{(\$/\text{mg})}{\text{unit price}} * \underset{(\text{litres/year})}{\text{volume of water}}$$

Recommendation 18: A quantified relationship between chemical additives (e.g., soda ash) and water pH (or between alkalinity and pH) is needed to calculate incremental chemical requirements for water treatment systems. However, no single relationship is appropriate for all Ontario systems. The feasibility and cost of determining such relationships for each treatment system should be further explored with the Drinking Water Section of MOE. Once these relationships are specified, the volume of incremental chemical requirements can be estimated and costed.

This approach to calculating incremental costs for systems which already have treatment procedures/equipment to counteract water aggressiveness is analogous to that derived by Victor and Burrell (1982).

Victor and Burrell (1982) also developed a methodology for calculating the economic impacts of increased water acidity for municipalities which do not have appropriate systems in place. The report suggests the incremental costs of acid deposition include the cost of purchasing, installing and operating water treatment systems where required by changes in water pH or aggressiveness.

However, discussions with representatives at MOE (John Toth, Gary Martin, Drinking Water Section) indicated that decisions to install water treatment systems are based primarily on the need to disinfect and remove particulates rather than considerations of pH levels.

Extra equipment needed to adjust pH levels are extra piping and a chemical feeder. This equipment may be included as an integral part of the design of a new water treatment plant to offset the effect hydrolysis has on pH levels. In these cases, there are no incremental capital costs attributable to acid deposition. The economic impact of acid deposition would consist only of incremental chemical requirement costs, as discussed above.

Two options for calculating the impacts of acid deposition on municipal water treatment systems are available.

Option 1: Calculate incremental chemical costs for existing water treatment systems only.

Option 2: **Calculate incremental chemical costs for existing water treatment systems and include a factor for incremental (pH-related) chemical costs in new systems.**

The first option may underestimate the economic impacts of acid deposition because it ignores future water treatment requirements. However, the criteria for installing new water treatment systems (e.g., water chemistry, forecasts of particulate content) cannot readily be incorporated into the MOE model. Consequently, the time and location of new systems -- and pH adjustments -- cannot be predicted. Option 2, therefore, necessitates a simplistic and somewhat arbitrary assumption regarding new pH adjustment practices. For example, it may be assumed communities/districts with water of pH less than 5.5 will be treated. This threshold value should be specified by the model user.

Recommendation 19: It is recommended that the model concentrate on incremental costs to existing systems in the economic impact calculation. Because this value may underestimate the total economic impact, an additional factor for chemical requirements at future treatment systems may be included, but should be activated the model user. In so doing, the user must specify threshold pH level(s), below which chemical treatment is undertaken.

5.5.2 Private Water Supply Systems

Victor and Burrell (1982) note that the approach to calculating costs of acid deposition to private water supply systems would be the same as for the public systems. However, several problems arise in actually calculating these economic impacts. First, to calculate incremental chemical costs requires an inventory of existing private systems -- and the pH of water treated in these systems. To our knowledge, no such inventory exists; nor does the reliability of data and relationships used in calculating incremental chemical requirements (e.g., the relationship between acid deposition and intake water pH) suggest this inventory should be considered a priority. Second, the problems with forecasting future private systems are the same as for public systems.

Finally, Victor and Burrell (1982) point out that private water supply systems are costly (because of size and location) and that, if the necessity arises, simpler and cheaper approaches could be developed. If cheaper systems do become commercially available, the chemical requirement approach may signficantly overstate the economic impact on private systems.

Recommendation 20: It is recommended that the MOE model not include the economic impact of acid deposition on private water systems.

5.6 Historic Buildings and Structures

One of the requisites for identifying the effects of acid deposition on historic buildings and structures is an inventory of structures at risk. Unfortunately, no comprehensive inventory exists with information on the number, location or type of material of historic structures. Two partial lists were obtained from Public Works Canada and Environment Canada. The Ontario sections of these lists are included as Appendix E.

The Public Works listing includes all pre-1942 buildings owned by Public Works (as of 1982). Short summaries of the buildings, including a description, history and types of materials are provided.

The Environment Canada list included in Appendix E covers buildings in Ontario which the Historic Sites and Monuments Board of Canada (HSMBC) and the Federal Heritage Buildings Review Office (FHBRO) have recommended be commemorated.

Environment Canada also has a Canadian Inventory of Historic Buildings (CIHB) which contains a listing of buildings with federal heritage designations. The list, which is computerized, contains information on location, construction dates, architects and builders, uses, building style and main exterior wall material. "Photo-cards" of the buildings are also available. The large bulk of the CIHB material precludes its inclusion in this document.

Additional information on historic buildings and structures is available from non-profit organizations. The Architectural Conservancy of Ontario is a non-profit organization set up to promote interest in and conservation of architectural structures of historic value. The Ontario Heritage Act enables municipalities to set up Local Architectural Conservation Advisory Committees (LACAC) to advise municipalities on local architectural conservation. The Act gives municipalities responsibility for designation of heritage buildings and for approving changes to structures. There are 160 LACAC's in Ontario.

Finally, the Ontario Ministry of Citizenship and Culture (Architecture and Heritage Planning Section) maintains a file of municipally-designated heritage structures. Because bylaws are different in each community, the level of information on each structure varies considerably. The file is currently a large manual system, although efforts are underway to allow access by computer.[10]

The federal Department of Environment has expressed some interest in initiating a comprehensive inventory of historic buildings and structures. The task, undertaken on a national basis, would amalgamate and synthesize information from existing sources, including their own list (Martin Weaver, Heritage Canada Foundation, personal communication). The final product would provide the most comprehensive single inventory of historic buildings and structures available (without additional field research) for Canada and a basis for further development.

Recommendation 21: A partial inventory of Ontario historic buildings and structures is given in Appendix E. The computer listing of the Canadian Inventory of Historic Buildings is available from Environment Canada. It is recommended that MOE monitor efforts by other parties (in particular Environment Canada) to develop a comprehensive database.

The literature contains only anecdotal information on the effect of acid deposition on historic buildings and structures. Victor and Burrell (1982) suggest that the value of the effect of acid deposition on historic buildings and structures could be approximated as the cost of repairing the associated deterioration. As the authors correctly point out, repair costs are an imperfect measure of the true value of retaining these resources. As discussed in Appendix B, economic value is based on a concept of "willingness to pay" for a good or service. Society (or individuals) may be willing to pay more than the cost of repairs; they may be willing to pay more to ensure, for example, the integrity of original artistic features. Consequently, the repair cost approach may underestimate the full economic cost of deterioration.

Conceptually, the full economic value could be estimated using a contingent valuation method which asks individuals what they would be willing to pay to avoid the effect of acid deposition on historic resources. This approach requires primary data collection (e.g., surveys) for a variety of Canadian heritage buildings and structures. This approach is outside the scope of the current model review and update.

Although the repair cost approach is suggested, model users should be fully aware that the estimated costs are only roughly indicative of the economic impact of acid deposition on historic buildings and structures. In addition, repair costs estimated from case studies (as suggested in Victor and Burrell, 1982) include costs of damage from all atmospheric pollution, not just from acid deposition. Quantitative information on the proportion of total damage attributable to acid deposition is not available. Where acid deposition constituents account for only some of several corrosive agents, the repair cost approach may overestimate the costs of acid deposition.

Numerous individuals in the federal and provincial governments and a non-governmental agency were contacted to obtain case studies of repair and restoration costs. No studies specific to acid deposition have been undertaken. Case studies relating costs of general air pollution have been completed in other jurisdictions.

Recommendation 22: Repair cost case studies for historic buildings and structures should be undertaken. The results should be written up separately from the computer model because their basis and coverage differ significantly from other components of the model.

5.7 Review of Victor and Burrell Recommendations

5.7.1 Physical Effects

Victor and Burrell (1982) recommend that research be undertaken into the specific impacts of acid deposition on buildings and structures, rather than rely on extrapolations from studies of general air pollution; and that synergistic effects of acids with other pollutants should be included. In light of the dearth of quantitative data available, this recommendation is still very relevant and worth repeating.

In particular, research should be undertaken on actual corrosion rates of materials at specific sites in Ontario and correlated with deposition, exposure and climatic variables. These data can then be used as controls to compare with quantitative relationships which become available in the general literature.

Recommendation 23: As recommended by Victor and Burrell (1982), research should be undertaken on actual corrosion rates of materials at specific sites in Ontario and correlated with acid deposition (vs. SO_2 or other proxies), exposure and climatic variables.

5.7.2 Economic Valuation

Two recommendations forwarded by Victor and Burrell (1982) focus on the quality of data used for economic life, exposure factors, thicknesses of materials and the inventory of buildings and materials at risk. Given the status of the physical damage relationships, extensive data collection and manipulation to estimate values "specifically for Ontario" do not appear warranted at this time. Instead, we suggest the values drawn from Salmon be verified through discussions with material experts (see Section 5.8.2). Until actual inventory data are available, Ontario's standing stock of materials can be described in physical rather than dollar terms by converting consumption into volume units, using average price data.

Finally, Victor and Burrell (1982) recommend that "carefully selected case studies of the economic implications of corrosion of specific materials in place be undertaken. These studies are important for those materials the economic cost of which may be many times less than the economic value of damages caused by component failure." As discussed in Section 5.3.4 above, in service valuation requires data collection and analysis efforts which do not appear warranted by the current level of scientific understanding of materials damage.

5.8 Data Requirements and Availability

5.8.1 Data Requirements

The following data must be assembled to operate the revised human systems model:

Data Requirement	Comment	Referred Disaggregation
A. Materials		
1. Population	update	by county
2. Materials consumption and average prices	revision & update	by material
3. Economic life of material	verify data	by material
4. Material exposure factors	verify data	by material
5. Population growth forecasts	new data	provincial
B. Water Supply Systems		
1. pH of intake water	new data	by treatement system/community
2. Volume of water treated (average flow)	new data	by treatment system/community
3. Price of chemicals	new data	by chemical

5.8.2 Data Availability

Population data are readily available from Statistics Canada. Population forecasts should be taken from macroeconomic model simulations used in forecasts of agriculture and forestry production.

Economic life and exposure factors should be verified by material experts. Relevant people can be contacted through organizations such as the:

Zinc Institute, NY, NY
International Lead-Zinc Research Organization, NY, NY
Portland Cement Association, Skokie, Illinois
International Copper Research Association, NY, NY
Copper Development Association, NY, NY
American Iron & Steel Institute, Washington, D.C.
Steel Structures Painting Council, Pittsburgh
Aluminum Association, NY, NY
National Association of Corrosion Engineers, Houston, Texas
American Society for Testing & Materials, Philadelphia, P.A.
American Society for Metals, Metals Park, Ohio

New data for economic life, value added and exposure factors are required for steel. The following values from Salmon (1970) can be used until Ontario-specific information becomes available:

economic life	18 years
value added factor	2.3
exposure factor	.02

Material consumption data may be gathered from several Statistics Canada publications. The volume and value of production is available from the following catalogues:

Concrete	44-219
Zinc	26-201/2
Aluminum	41-230
Copper	26-201/2
Paint	46-210

Information is not available for carbon and weathering steels, but only for the generic commodity group "steel" (see

Statistics Canada catalogue 41-231). These publications include provincial disaggregations.

Production data must be adjusted for imports, exports and inventories to give estimates of materials consumption. National import and export data are available in detailed annual tables in Statistics Canada catalogues 65-202 and 65-203. Inventory information is included in the commodity publications noted above.

For water supply systems, data on intake water pH is available from the Drinking Water Section of MOE (contact Ann Vajdic). Data are/have been collected under two programs. The new program -- the Drinking Water Surveillance Program -- collects data on intake and treated water at 16 locations. The older program -- the Utility Monitoring Information System (UMIS) -- has been operating for 5-10 years and is run by the Water and Waste Water Management Division of MOE. Data is collected from 85 plants in six Ontario regions, with some overlap with the new program. Data in the UMIS include intake water pH for most but not all plants. The UMIS also includes average flow data for each plant.

Preliminary chemical prices are:

	$ per 100 kg
$NaHCO_3$ (industrial grade)	69.25
Na_2CO_3 ("light soda ash")	26.60
$Ca(OH)_2$	65.40

Source: based on data from G. Martin, MOE.

These prices include transportation to southern Ontario only, and exclude taxes and duty. More detailed information on prices can be collected from producers and distributors:

Canada Colours	416-449-7750
Domtar	- 519-423-6261

FOOTNOTES

1. Only one recent document which identifies impacts (specific to acid deposition) was identified during the literature review: see Sherwood & Wippert (1984).

2. Note: The reference cited uses the terms "sulfur pollution" and "pollution" interchangeably.

3. "Structure temperature" is the temperature of the outer wall of the structure. Structure temperature may differ from ambient temperature because of radiation effects, internal heating, etc. "Deposition velocity" captures the ability or tendency for a surface material to absorb ambient SO_2.

4. The Battelle study examines the effects of general air pollution, although some references are made to accelerated corrosion of zinc by SO_2.

5. Calculated as follows:

   Assumptions:
   Tw (wet-time measurement for temperature) = 7.9°C
   (AES, Ontario)
   W (time of wetness /elapsed time) = 143 days (39%)
   (AES, Ontario)
   t (time of exposure in years) = 365 days
   thickness (Salmon, 1970) = 0.15 in.

   Equation a):

   $$\text{Corrosion (um) } Q = (0.068 + 1.16Sw) + 0.0038Tw - 0.0005Tw^2 + 0.24W + 0.016Tw)t$$
   $$= 0.0184 + 0.0445SO2$$
   $$= (1.84 + 4.45SO2)x10^{-2}$$

   Equation b):

   $$\text{Corrosion (um) } Q = 0.63\ (Sw + 1.78)t{*}W^{0.706}$$
   $$= 0.0039 + 0.0022SO2$$
   $$= (3.9 + 2.2SO2)x10^{-3}$$

6. Interaction values calculated as follows:

   Assumptions: tw = 29 (Stanners, 1972)
   thickness = 75 um (as used in the 1980 model)

   $$\text{Thickness loss (um)} = Y = (2.4 + 0.045\ SO2)tw$$
   $$= 0.696 + 0.013SO2$$

   Interaction Value (including dry deposition)

   $$= (0.696 + 0.013\ SO2/75$$
   $$= (92.8 + 1.73SO2)x10^{-4}$$

   Interaction Value (wet deposition only)

   $$= (0.696 + 0.013\ SO2)x0.4/75$$
   $$= (371.2 + 6.96SO2)x10^{-5}$$

7. Treatment may also include filtration and post-disinfection.

8. At present, pH is adjusted prior to distribution in only a few systems; however, adjustment may become more common as intake water becomes more acidic.

9. A survey of groundwaters in the Sudbury area in 1981 suggested that "because of the demonstrated dependence of pH on CO_2, it would appear that acid precipitation has not affected groundwater to a great extent in the Muskoka and Sudbury areas" (Sibul and Reynolds, 1982).

10. For further information contact:
    Sheila Larmer
    Architecture and Planning
    Ontario Ministry of Citizenship and Culture
    416-965-4961

6.0 MODELLING ENVIRONMENTS

6.1 Audit of the 1980 Model

There were two objectives of the audit of the 1980 model. The first objective was to analyze the performance of the existing computer program by examining its structure and programming language. The second objective was to review and understand the computer models for human systems, agriculture, and forestry. The reviews covered:

- databases;
- identification of and assumptions for key operational variables and parameters;
- dose-response relationships; and
- details of the economic valuation methodologies.

The audit entailed a review of the documentation and computer code for the models. In addition, the model was accessed from the Downsview computer and several simulations run. Data files were listed and documented results were duplicated. Various sensitivity tests were undertaken to identify key operational variables and to confirm and clarify documentation.

Descriptions and logic flow diagrams for each of the three models (i.e., human systems, agriculture, and forestry) are included in the sectoral discussions in Sections 3, 4, and 5. The focus of this section is the assessment of the model's structure and programming language. The five main conclusions of the audit are discussed below.

6.1.1 Modelling Environment

The model is implemented in the Interactive Financial Planning System (IFPS) at a large mainframe computer in Downsview, Ontario. The major strength of this system is that it provides a very good environment for model development. The IFPS software has a number of features, such as flexible data input (i.e., data do not have to be rigidly formatted or structured), debugging procedures, and report generation which facilitate model development.

6.1.2 Ease of Use

The 1980 model may be characterized as a prototype. Its programming language and format suggest that during development more emphasis was placed on providing an operational model than ensuring ease of use by a variety of users. Apart from documentation provided by Ontario Hydro, there is no interactive module to prompt the user. (Indeed, without the Ontario Hydro documentation, understanding, accessing and running simulations on the model would be very difficult.)

It is also very difficult for the user to make changes to the model -- either to the data, to parameters, or to the program code itself. For example, some reprogramming was required to carry out sensitivity tests during the audit of the model. Given the inherently high degree of uncertainty in many of the dose-response relationships, parameters, and other data used to estimate the impacts of acid deposition, it is extremely important that changes and extensive sensitivity testing can be done with ease.

Scenario specification in the 1980 model requires a detailed understanding of the structure of the model, code names and where the code names occur throughout the model. As the model currently stands, there are numerous coefficients embedded in the code and it is difficult to know what changes are being made. It is also difficult to ensure the consistency of those changes because the same code name occurs in different parts of the code.

6.1.3 Model Maintenance

The 1980 model's single most significant difficulty, as identified during the audit, is ease of maintenance. Maintenance of the program code is inhibited by two major factors. First, some parameters are in the program as constants, rather than being easily accessible through a data file. This structure makes it difficult to identify or to change, check, or document parameters. Second, the model is not adequately structured in modules to facilitate identification of information flow. In some instances, it is inefficient and repeats similiar or identical equations throughout the code. A modular structure would significantly simplify changes to the program code and data.

With respect to data maintenance, the IFPS software has extremely limited data management capability, creating significant problems if any further detail on regions or species are required. Exhibit 6.1 shows an example data file. The lack of descriptive material in or documentation to the file (e.g., variable names, units, headers) inhibits quick and efficient changes to the data.

6.1.4 Cost Effectiveness

Notwithstanding the considerable amount of data which the model handles, the computer code necessary to run equations is fairly short. Thus, overall memory and space is not an important issue in choosing appropriate software and hardware for the program. The model could be run on a personal computer. The expense of running IFPS on the Downsview mainframe computer is not necessary. The Downsview computer simplifies Monte Carlo simulations, which are part of the 1980 model; however the Monte Carlo method could be implemented on personal computer with some loss in response time but at a lower cost.

EXHIBIT 6.1: SAMPLE OF 1980 MODEL DATA FILES

```
 FILE R1 02/17/86 15:30
FACBYS1= 0
FACBYS2= 0
FACBYS3= 0
FACBYS4= 93
FACBYS5= 0
FACBYS6= 0
FACBYS7= 0
FACBYS8= 2480
FACBYS9= 1695
FACBYS10= 0
FAACS1= 0
FAACS2= 0
FAACS3= 0
FAACS4= 92.5
FAACS5= 0
FAACS6= 0
FAACS7= 0
FAACS8= 2480
FAACS9= 1695
FAACS10= 0
UTHBY= 40262.5
UHT= 47000
ATPAS1= 23176.74
ATPAS2= 1132756
ATPAS3= 273621.34
ATPAS4= 851450
ATPAS5= 21164144.4
ATPAS6= 0
ATPAS7= 107148
ATPAS8= 1056619.83
ATPAS9= 56405
ATPAS10= 34386992.8
ATPAS11= 2187.9
ATPAS12= 437.5
ATPAS13= 0
ATPAS14= 9666442
ATPAS15= 5163939.8
ATPAS16= 5749262
ATPAS17= 37382.4
ATPAS18= 1062301.72
ATPAS19= 219588
ATPAS20= 10606913
ATPAS21= 13136813
ATPAS22= 5878860
ATPAS23= 1051341
ATPAS24= 1326750
ATPAS25= 602.8
ATPAS26= 4566870
ATPAS27=1714.7
ATPAS28= 0
ATPAS29= 12169
ATPAS30= 6874980
ATPAS31= 50022256
ATPAS32= 8883000
ATPAS33= 560000
ATPAS34= 10058
ATPAS35= 320000
ATPAS36= 17354700
FBS= .65
FCEC= 27
FPXC= 55
FTPFA= 168
PRX= 76
PHEX= 45
CSO4= 145
CNO3= 55
CNH4= 35
ATPA= 693059
ATPANL= 414361
UCOST= 436625
REGF=406313.55
END OF DATAFILE
```

```
READY FOR EXECUTIVE COMMAND


FILE R2 02/17/86 15:31
FACBYS1= 0
FACBYS2= 0
FACBYS3= 0
FACBYS4= 877
FACBYS5= 218
FACBYS6= 93
FACBYS7= 225
FACBYS8= 13217
FACBYS9= 16259
FACBYS10= 0
FAACS1= 0
FAACS2= 0
FAACS3= 0
FAACS4= 877.1
FAACS5= 218
FAACS6= 93
FAACS7= 225
FAACS8= 13217
FAACS9= 16259
FAACS10= 0
UTHBY= 85240.52
UHT= 88280
ATPAS1= 84889.98
ATPAS2= 4096401.8
ATPAS3= 1256879.32
ATPAS4= 1610305.2
ATPAS5= 37470362.3
ATPAS6= 46518
ATPAS7= 2970200.9
ATPAS8= 4680943.88
ATPAS9= 753947
ATPAS10= 23968965.2
ATPAS11= 18287.27
ATPAS12= 3641.5
ATPAS13= 163121
ATPAS14= 6754324
ATPAS15= 60357395
ATPAS16= 9693447
ATPAS17=530452.9
ATPAS18= 1557703.09
ATPAS19= 3367574
ATPAS20= 9262237
ATPAS21= 38568957
ATPAS22= 17429721.9
ATPAS23= 9300368
ATPAS24= 2243479
ATPAS25= 14877.24
ATPAS26= 1773186
ATPAS27= 82383.22
ATPAS28= 1170440
ATPAS29= 19957.09
ATPAS30= 5223216
ATPAS31= 156922284
ATPAS32= 590710
ATPAS33= 27313480
ATPAS34= 34408.16
ATPAS35= 1356400
ATPAS36= 8137104
FBS= .65
FCEC= 22
FPXC= 65
FTPFA= 762
PRX= 86
PHEX= 50
CSO4= 130
CNO3= 60
CNH4= 45
ATPA= 1606826
ATPANL= 1380504
UCOST= 1099263
REGF=499251.7
```

6.1.5 Management of Spatial Data

In reviewing the 1980 model, it became apparent that manipulation of input data on a geographical basis was as important as the model equations themselves. The 1980 model breaks the province into 64 regions and all data are manipulated to fit this framework. Results are reported on the same basis. The 1980 framework was probably the best that could be used at that time. It is based on an ecological divisions of Ontario considered significant for forestry. These divisions or site classes reflect soils features, climate, and geology.

The disadvantage with the 1980 fixed framework is that all other data have to be manually converted to the 64 regions by interpolating, extrapolating, and prorating from the data's original geographic disaggregations. For example, agriculture production data are converted from a county basis; population data from census divisions. To revise regional data, the user must recalculate them from the spatial disaggregations of the original data. This manual manipulation is time consuming and, unfortunately, the methods used to convert data to the 64 regions in the 1980 model are not included in the model's documentation.

In summary, the major strength of the 1980 model structure/language is that it provides a very good environment for model development through features such as flexible data input, debugging procedures, and report generation. However, the model has not been extensively used, and the model's location (a large, somewhat forboding computer system) does not lend itself to use by computer novices. If the model is intended for active use by several people for policy and research planning, then it should be more "friendly" and accessible. This could be accomplished by moving it to a personal computer and by restructuring the data management capabilities.

6.2 Recommendations for Modelling Environment

6.2.1 Options

In this section, some major options for modelling environments are presented with discussion of their feasibility and utility.

(a) Status Quo

All of the changes to the model recommended in this report could be made to the 1980 IFPS (mainframe) model. Input data would have to be massaged manually to create more up to date information for the model. This approach would, however, not overcome problems outlined in Section 6.1 above. Furthermore, it is unlikely that the model would be used any more than it has been in the past.

(b) Personal Computer (PC) Model

To make the model more accessible and approachable, it could be transferred to a micro-computer. A version of IFPS exists for an IBM micro-computer, but it does not support Monte Carlo simulations. If Monte Carlo simulations are desired, data and parameter values can be transferred from the micro to the mainframe model.

The model could be re-written in Fortran or Basic to the IBM PC with limited programming effort. A Monte Carlo version would be fairly simple to develop in one of these programming languages. Another option would be to implement the model in a spreadsheet program such as Lotus. This option might be cumbersome to program but very easy to use as many people today are familiar with spreadsheet programs. Furthermore, program documentation and debugging tools exist for Lotus 123 and its derivatives.

(c) IFPS and Geographic Information System (GIS)

An option that would improve data manipulation would be to use a GIS to generate input data and perhaps to aggregate model output. The process of reconciling the various spatial resolutions of the data would be more flexible and easier to document. GIS options are discussed in more detail in Section 6.2.2 below. The model equations would be run under IFPS on the mainframe computer as is presently done.

(d) PC Model and GIS

An IBM compatible micro-computer could run the model in conjunction with a GIS system. Spatial data could be manipulated using the GIS and transferred to the PC model (and back if appropriate).

(e) SPANS Meta Language

The SPANS GIS system contains a meta or programming language. This language is used to construct complicated expressions of spatial data and to overlay these calculations on the other data sets. It would be possible to express the simulation model in this meta language and use it as a means of combining and overlaying the spatial data directly. Such an exercise would be experimental as no one, to our knowledge, has attempted to integrate a time structure simulation model into a geographical information system.

An integrated simulation model and GIS would be very attractive for several reasons. For example, the agricultural soils calculations could be done on the spatial resolution of the soils data and the production calculations could be done on their particular spatial resolution. The output of these two sets of calculations could then be overlayed on one another to calculate overall economic impacts. This process would make each model more defensible in its own right as it would not rely on manipulation of input data to a common spatial resolution before calculations are done.

These options were discussed with MOE representatives. Particular attention was paid to accessibility, reprogramming requirements, and cost. For example, a PC version would allow more widespread use of the model, but transferring to a program other than IFPS/PC would require additional reprogramming.

Recommendation 1: In consideration of current budgets, the model could remain on IFPS at the Downsview computer with two amendments. First, the use of a computerized GIS should be introduced to improve data management. Second, the model should be available on a PC version of IFPS.

Recommendation 2: To overcome problems of ease of use and model maintenance (as outlined in Section 6.1), it is suggested that either front and back ends be added to the 1980 model or the code be rewritten in its entirety. The latter option is preferable because it would enhance the efficiency of the model and, more importantly, ease of maintenance without significantly more effort than the first option.

6.2.2 Geographic Information Systems

Introduction of geographic information system technology and the general availability of micro-computer based GIS render the 1980 fixed geographic framework obsolete. Instead, overlay analysis of the various geographical boundaries can be performed to create true regions representing the data being used. There are three options:

- full integration of a GIS into the modelling framework
- use of a GIS for data input
- use of a GIS for data input and display of results with data transfer to and from the model.

While less expensive than the first option, the third option allows for pictoral (i.e., map) presentation of the model's results to supplement numeric output.

Recommendation 3: It is recommended that a GIS be used for data input and display of results with data transfer to and from the model.

Implementation of the recommended approach raises a number of issues, including:

- access to a GIS
- data entry
- region identification
- interpolation of results
- results format
- interface with IFPS.

Access. The MOE may be able to access a GIS residing in another department of the Ontario Government (e.g., Ministry of Natural Resources). These in-house systems should be identified and evaluated in terms of requirements for the acid deposition model.

Data Entry. To perform overlay analysis, the various maps containing Ontario data must be converted to machine-readable form. The data entry system of any topologically based GIS can be used to create these map databases. Each polygon will require an associated attribute file in which regional characteristics are stored.

If digital mapped data are already available, an interface may be required to enable the GIS to be used. This is a minor problem as the data sets are small and could be re-entered specifically for this project.

Numeric data can be input directly into an attribute file for each region or for the province as a whole.

Regional Identification. As the geographic units are not expected to change frequently, the regional database created by a GIS may remain useful for several years. The sector models will always be run separately, with an aggregate of results. The most efficient approach to data management is to create a unique polygon map for each sector model. This approach would make maximum use of all data without forcing -- or hand manipulating -- data in different geographic regions, as is done in the 1980 model.

For example, agriculture and forestry may require component maps by geographic bases as shown in Exhibit 6.2. The forestry maps would be overlayed to produce a map showing the unique conditions for forestry. The same would be done for agriculture. The two unique conditions maps show all areas which are differentiated by values of one or other attribute. For example, each area shown on the agriculture unique conditions map would have a unique combination of soil types, production and deposition levels.

The attributes for each unique condition (e.g., deposition level, soil type) are stored in an attribute file, in the following sample format.

Unique Area	**Soil Class**	**Annual Production (mill. tonnes)**	**Sulfate Desposition**	**Nitrate Deposition**
			(meq/m^2/year)	
1	A	5.0	13.5	7.5
2	A'	12.5	24.0	10.0
3	B	6.5	31.0	14.0
.				
.				
.				
N				

Data in the attribute files are then transferred to the model's equations to generate the effects of acid deposition for each unique region. Different deposition scenarios are examined by running the model with modified deposition attributes.

Interpolation of Results. It is likely that creation of the unique conditions maps will result in a large number of unique regions. Display of the results will probably resemble a patchwork quilt with many hundreds of very small areas. To facilitate presentation, two issues must be addressed:

EXHIBIT 6.2: EXAMPLES OF REQUIRED GEOGRAPHIC DATA

Inputs	Geographic Unit	Approx. No. of Polygons
Agriculture		
Soils	Generalized Soil Map	300
Production	County*	1,000
Forestry		
Soils	Generalized Soil Map 1:1,000,000	300
Max Allowable Depletions	Management Units	±100
Production/Harvest	Management Units	±100
Deposition		
Sulfates	Appropriate geographic disaggregations to be determined in consultation with Air Resources Branch (MOE)	
Nitrates		
Dry		

* Alternatives are Census Divisions, Census Sub-Divisions.

- grouping results into classes for display, and
- generalizing small unique regions to produce understandable results.

The GIS to be used may, or may not, have the ability to perform these operations once the model results are known and have been added to the unique conditions attribute file. In selecting a GIS, the MOE should consider the need to interpolate model results.

Results Format. Alternatively, the results could be reported in tabular form and manually plotted on a line map showing the unique region. There may be a need to report results by other regions such as political constituencies, municipal units, or watershed. Unless these needs are predictable, these regions should not be included in the unique conditions report as the number of regions, hence processing time, would increase unnecessarily. Instead, the GIS to be used should have the capability of overlaying the results with a new map of the desired regional disaggregation and of averaging results by these regions.

Interface between Model Computer and GIS. There are two considerations in interfacing the GIS and the model's computer. First, the attribute files must be in units and expressed in a way that is acceptable to the model. For example, a map usually has classes with upper and lower bounds. The model requires a mid point of this class or other single entry for the region in question. Second, once a GIS has been selected, an interface will be required between the attribute files of the unique conditions map and the model input table. This is a straightforward task.

6.3 Revisions to Computer Code

Four types of changes for the three sector models have been noted in the code listing. They are:

(1) Changes to equations or formulae to incorporate

suggested revisions to dose-response relationships and/or economic valuation methodologies.

(2) Corrections to the 1980 code.
(3) Changes to data embedded in the code.
(4) Revisions to data files.

The sources for revisions to data are explained in Sections 2.3, 3.5, 4.5 and 5.4 for the deposition, forestry, and agriculture and human systems sectors, respectively.

The revisions noted in the code are specified in sufficient detail to allow a programmer to complete the changes without undertaking further research or analysis. Because of the complexity of the code, it is suggested that these changes be made by the original programmer, or someone familiar with the code.

With access to IFPS/PC software and documentation, the model can be downloaded from the mainframe version. The programmer should specifically examine how IFPS/PC software would handle the random variables TRIRAND and UNIRAND. If IFPS/PC does not automatically take the mean values of the distributions, the random number generator sections may have to be extracted from the code. The code revisions do not include changes to the program structure or language.

Sections of the computer code with revisions are listed in Appendix F.

7.0 SUMMARY OF RECOMMENDATIONS

The review of the 1980 MOE acid deposition models indicated that their structures are essentially sound. However, changes concerning specific components of individual models (e.g., dose-response relationships, economic valuation) are recommended. These recommendations are summarized below for each sector model (i.e., deposition, forestry, agriculture, human systems), along with recommendations on the general economic valuation framework and modelling environments. Each recommendation is referenced to its discussion in the text.

7.1 General Economic Valuation Framework[1]

The current public financial framework should be maintained with impacts calculated from the perspective of society at large. This approach requires estimates of effects on consumers as well as producers (pg. B-6).

In drawing conclusions from model simulations, consideration should be given to the offsetting effects that mitigative actions or substitutions may have on economic costs (pg. B-13).

Distributional and social consequences are often important criteria in evaluating government actions and projects. For this reason, it is recommended that employment impacts be estimated and included in the model output where appropriate[2]. Other distributional and/or social impact indicators can be considered in the future.

7.2 Deposition Model

The separation of natural and anthropogenic deposition should be eliminated (pg. 2-3).

The new model should allow the user to adjust the mix of ions in the deposition. To do this, acid deposition data for each of the four ions (hydrogen, sulfate, nitrate and ammonia) should be input separately (pg. 2-3).

For above-ground effects in forestry and agriculture, wet deposition levels should be calculated for the active growing season (defined as May to October). For soil effects, total annual deposition should be calculated, but prorated by some user-specified parameter. The default value for the parameter should be 65% (i.e., 65% of annual deposition remains in the soil). For human systems, deposition levels over the year should be calculated (pg. 2-4).

There should be two deposition parameters for hydrogen ions. The two parameters relate to above ground and soil effects which can be differentiated by the user. The default in the computer program should equate the hydrogen ion parameters (pg. 2-4).

Dry deposition data should be added to wet deposition in calculating soil impacts for forestry and agriculture and for calculating impacts on human systems (pg. 2-4).

Average annual water pH should be calculated for the water supply component using the same methodology as in the 1980 model; average growing season pH should be calculated for above ground effects in the forestry and agriculture models (pg. 2-5).

The pH range for simulations should be limited to "realistic" average levels calculated over a given time period (annual or growing season) and variations of: $3.5 < pH < 5.5$ (pg. 2-5).

7.3 Forestry Model

It is suggested that the term "yield" be clarified to distinguish between biological and economic forest production. The revised model should use the term "potential yield" as a measure of forest productivity (e.g., cunits per hectare) while total quantity of wood harvested or "harvested yield" should refer to economic forest production (pg. 3-7).

Above Ground Effects

The model's capability for identifying three sensitivity classes should be maintained but a default should be introduced which reduces sensitivity classes to one (pg. 3-9).

The intercept on the foliar dose-response relationship should be set to 3.5 so the expected foliar effect of acid deposition will be zero at pH of 3.5. Monte Carlo runs using the 1980 structure but with the new intercept could provide an indication of how sensitive the overall model is to this assumption (pg. 3-9).

Soil Effects

The only recommended change to the base saturation equation is to drop the nitrogen fixation term. Enhanced cation uptake by wood because of nitrogen fixation is already incorporated by the term dealing with change in potential yield (pg. 3-10).

The change in potential yield should be made a direct function of base saturation (instead of function of change in exchangeable calcium). Because of a lack of data on the relationship between base saturation and tree growth, this function can be assumed to be linear (the simplest functional form with least data requirements). At the time of this report we are unable to make any suggestion regarding the value of the parameters (pg. 3-10).

Change in current annual increment (CAI) due to nitrogen fertilization can be assumed to be:

$$\text{CAI} = \text{Base CAI} * (1 + .0011 * \text{N kg/ha})$$

This increase in growth should not continue unconstrained; a saturation level at maximum growth increase of 25% over a five-year period should be introduced (pg. 3-10).

The amount of mobile aluminum should remain constant until base saturation drops below some critical point. Then all the hydrogen input can be assumed to liberate aluminum and other trace metals. The calculation of the effect of aluminum on tree growth or yield should remain the same as in the 1980 model. At the time of this report, we were still unable to find appropriate parameters for the model (pg. 3-11).

Economic Valuation

At this time, the assumption that the total quantity of wood extracted will not be affected by acid deposition should be maintained on the premise that the effect on potential yield is small. However, should scientific evidence suggest otherwise, it is recommended that Maximum Allowable Depletion (MAD) be linked with changes in potential yield as outlined in Section 3.3.3 (pg. 3-14). These changes would require further modifications in the economic valuation formula (see Appendix D).

Data on annual allowable cut should be replaced with MAD values for five year periods in a 20 year timber management planning horizon. When the data become available, these figures should be adjusted for harvestable portion (pg. 3-14). The adjusted MAD provides a control for unconstrained growth of actual cut, as follows[3] :

Actual Harvest (ha.) = minimum [harvest previous year (ha.) *
(1 + growth factor); (adjusted) MAD
(ha.)]

The formula states that actual harvest will be the minimum of (adjusted) MAD and last year's harvest with some increase (pg.3-15).

Changes in delivered wood costs should be related to changes in an appropriate measure of productivity (i.e., potential yield measured in cunits per hectare) instead of tree size (pg. 3-18).

Delivered wood costs should be redefined as a function of potential yield. A relationship between potential yield and delivered wood costs should be developed based on simulation data from FORCYTE or from a survey of private operators in Ontario's wood industries (pg. 3-20).

The estimate of unit delivered wood costs should be updated to the most current information (pg. 3-20).

Production and price forecasts for each sector should, to the extent possible, be based on a common set of macroeconomic assumptions. A common and consistent set of assumptions can be drawn from CANDIDE or RIM macroeconomic models. It is recommended that MOE pursue discussions with operators of CANDIDE or RIM to develop indices of future prices and production for forestry. These national projections can be adjusted to account for Ontario's changing share of national output, based on historical data, output from RIM or the Conference Board model (pg. 3-22).

7.4 Agriculture Model

Above Ground Effects

Scientific evidence does not support crop-specific dose-response relationships. A single stochastic dose-response relationship for all crops should be used. A review of previously estimated relationships presented in Irving (1983) forms the basis for this function (pg. 4-8).

Sugar maples should be added as a crop type, subject to the same dose-response relationship as other crop types for above ground effects. No soil management amendments should be included for maple sugar (pg. 4-11).

Soil Management

Sulfate deposition up to 10-30 kg/ha (using 20 kg/ha as a default) should be included as a benefit. Sulfate deposition above this level should be included as neither a benefit nor cost (pg. 4-13).

The effects of sulfate deposition accounted for in the liming requirements should be equal to the hydrogen ion input plus a component for sulfate deposition (pg. 4-13).

Economic Valuation

The formula P(Q'-Q) + (TC-TC') should be replaced with the general formula for estimating changes in economic welfare, to take into account possible changes in market price (pg. 4-16). The user should activate price effects (where prices are sensitive to changes in quantity) by specifying an elasticity for each crop group. The model default should set price effects to zero (pg. 4-20).

It is not recommended that the model include quality impacts as they are highly case-specific and adequate biophysical data do not exist (pg. 4-17).

Soil amendment costs should be updated to the most recent available data using information from the Ministry of Agriculture and Food (pg. 4-17).

The current assumption that all farmers will adapt soil amendment practices perfectly should be maintained. However, it should be noted that this assumption will tend to overestimate cost savings and underestimate higher costs of soil amendment practices (pg. 4-18).

Projections of prices and output for the agricultural model should be accessed from the CANDIDE or RIM models. Modifications of growth trends should then be made to reflect provincial and species-specific changes in shares of agricultural output. The RIM or Conference Board models could assist in developing provincial specifications (pg. 4-21).

7.5 Human Systems

Materials Damage - Physical Effects

MOE should proceed with the 1980 material category approach to estimating the effect of acid deposition on materials. This approach should use corrosion formulae for dose-response relationships; however, damage estimates and conclusions should be couched in appropriate terms of uncertainty. MOE should also monitor and, to the extent possible, contribute to the development of methodologies for estimating materials at risk and Ontario-specific corrosion formulae (pg. 5-14).

The model should relate sulfate (not $H+$) to SO_2 with the conversion factor specified by the user. A default factor based on equivalent atomic weights of sulfate and SO_2 should be input (pg. 5-15).

The effects of dry deposition should be incorporated by eliminating the 40% adjustment as interaction values (pg. 5-15).

The 1980 corrosion formulae for concrete, marble and aluminum should be maintained because no new information is available (pg. 5-16).

It should be recognized that estimates for damage to paints are particularly subject to error because the methodology assumes that one corrosion rate is applicable for all paint types and that repainting occurs after total surface corrosion. Furthermore, the estimates do not consider the quality of surface preparation. Lack of data preclude any improvements to the 1980 interaction value (pg. 5-16). Nickel should be excluded from the model because data indicate it is not significantly affected by acid deposition (pg. 5-17).

Carbon and weathering steels should be added to the set of materials for which damage is estimated (pg. 5-20). The interaction values should be applied as follows:

(a) $(1.84 + 4.45SO2)x10^{-2}$ for SO_2 deposition ≤ 40 ug/m^3
(b) $(3.9 + 2.2SO2)x10^{-3}$ for SO_2 deposition ≥ 80 ug/m^3
(c) an average of the two interaction values for intermediate levels ($40\ ug/m^3 < SO_2 < 80\ ug/m^3$) of SO_2 deposition (pg. 5-23).

The 1980 formula on which the interaction value for zinc is based should be replaced, and the following interaction value used (pg. 5-24):

$(92.8 + 1.73SO2)x10^{-4}$

Materials Damage - Economic Valuation

The current structure of the economic valuation methodology should be maintained: however, it should be noted that the exclusion of soiling and substitution will **ceteris paribus** underestimate the economic costs of materials damage (pg. 5-28).

Material stock data should be updated. Stock data should be based on consumption (versus production) where possible, and averaged over several years (pg. 5-29). The stock of materials at risk should grow at the rate of population growth (pg. 5-30).

Economic life values used from Salmon (1970) should be verified with material experts in Canada (pg. 5-31).

Population data and population ratios should be updated to the most recent available information (pg. 5-32).

It is recommended that in-service valuation not be incorporated in the calculation of economic impacts of materials damage (pg. 5-33).

Water Supply Systems

The economic impact of acid deposition on municipal water supply systems should be calculated as the incremental chemical costs of raising intake water pH to its original level (pg. 5-36).

Changes in intake pH can be calculated from changes in the pH of wet deposition. In the absence of other data, the changes can be assumed to be proportional (i.e., if the pH of wet deposition falls x% then the pH of intake water falls x%). We emphasize that this relationship should be reviewed and modified as data and analyses become available (pg. 5-37).

A quantified relationship between chemical additives (e.g., soda ash) and water pH (or between alkalinity and pH) is needed to calculate incremental chemical requirements for water treatment systems. However, no single relationship is appropriate for all Ontario systems. The feasibility and cost of determining such relationships for each treatment system should be further explored with the Drinking Water Section of MOE. Once these relationships are specified, the volume of incremental chemical requirements can be estimated and costed (pg. 5-38).

The model should concentrate on incremental costs to existing water treatment systems. Because this approach may underestimate total economic effect, an additional factor for chemical requirements at future treatment systems may be included, but should be activated by the model user. In so doing, the user must specify threshold pH level(s), below which chemical treatment is undertaken (pg. 5-40).

It is recommended that the model not include the economic impact of acid deposition on private water systems (pg. 5-41).

Historic Buildings and Structures

A partial inventory of Ontario historic buildings and structures is available (pg. 5-41); however, MOE should monitor efforts by other parties (particularly Environment Canada) to develop a comprehensive database (pg. 5-43).

Case studies of restoration costs for historic buildings and structures should be undertaken. The findings, however, should be presented separately from results of the computer model (pg. 5-44).

7.6 Modelling Environments

Based on criteria of accessibility, reprogramming requirements and costs, it is recommended the model remain on the IFPS at the Downsview computer, but with two amendments. First, a computerized geographic information system (GIS) should be used to improve data management. Second, the model should be available on a PC version of IFPS (pg. 6-8).

The GIS should be used for both data input and display of results with data transfer to and from the model (pg. 6-9).

Funds and time allowing, the computer code should be rewritten to facilitate use by computer novices and, more importantly, to significantly enhance model maintenance (pg. 6-8).

7.7 Further Tasks

The following tasks must be completed in order to produce results from the revised model:

1. Choose and introduce a geographic information system
2. Collect necessary data and input to GIS attribute files
3. Make changes to computer code to include revisions outlined above and transfer the code to PC-based software.

To include suggested revisions requires the following tasks:

- identify growth rates and price projections for forestry and agriculture from macroeconomic models;
- determine fertilizer and liming costs;
- base the forestry economic component on the concept of Maximum Allowable Depletion (instead of Annual Allowable Cut); and
- collect data for the water supply systems component of the human systems model.

The recommendations also call for more involved tasks such as:

- determining the relationship between delivered wood costs and potential forest yield;
- verifying economic life and exposure factors for materials at risk;
- case studies of restoration costs of historic buildings and structures; and
- rewriting the computer code to improve model structure and facilitate its maintenance.

Finally, MOE should monitor research and activities of other parties. In particular, MOE should monitor and, when available, incorporate:

- scientific research into dose-response relationships for acid deposition, especially for forestry;

- efforts to develop an inventory of materials at risk (e.g., Leman methodology and prototype); and
- efforts to develop a comprehensive data base of Ontario's historic buildings and structures.

FOOTNOTES

1. See Appendix B for a discussion of these recommendations.
2. Impacts on employment will vary across sectors. In forestry, increased delivered wood costs may reflect increased employment as more manpower is required to fell a given quantity of timber. In agriculture, the MOE model assumes that harvesting and fertilizer application costs are not affected, so no employment impacts are expected in this sector. Increased frequency of material replacement will tend to generate employment in that sector.

APPENDIX A

LIST OF WORKSHOP PARTICIPANTS

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APPENDIX B

FRAMEWORK FOR VALUING THE IMPACTS OF ACID DEPOSITION

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FRAMEWORK FOR VALUING THE IMPACTS OF ACID DEPOSITION

The MOE models contain two parts: estimation of biophysical impacts of acid deposition and economic valuation of those impacts. The purpose of this appendix is to explore possible frameworks for the economic valuation of impacts. Three aspects of valuation frameworks will be addressed:

- the definition of impacts;
- identification of specific impacts to be valued; and
- appropriate, theoretically correct measures of impacts.

This section also offers recommendations for changes to the valuation framework.

B.1 Definition of Impacts

Any project or change in the use of resources generates two types of impacts:

- **Private impacts (costs and benefits)** accrue to the proponent or agency which initiates the project. Private impacts include changes in revenues, costs, or profits that result from the project.

- **Public impacts (costs and benefits)** are consequences imposed on individuals or firms not connected with the project proponent (Donnan, 1986).

In assessing the impacts of acid deposition, the "project" may be considered the production and release of acid gas pollutants. The costs of these pollutants are borne almost entirely by the public rather than by the emittors. The impacts of acid deposition, therefore, are considered to be public benefits or costs.

Public impacts can be categorized as:

- financial impacts;
- amenity impacts;
- distributional and social consequences.

Financial impacts capture the effects of acid deposition on marketable resources (e.g., forests, agricultural products, building materials). Financial impacts can be measured with reference to market prices, costs of production, and quantities produced. Financial impacts can be calculated from the perspective of the resource owner/user or from the perspective of society at large. Financial impacts from the perspective of the resource owner include changes in costs, revenues, and profits.

To calculate financial impacts from the perspective of society at large requires three modifications to the resource owner's or producer's impacts. First, impacts on consumers must be added. In economic jargon, valuation from the resource owner's or producer's perspective would include only producer surplus, while the societal perspective includes both producer and consumer surpluses. As explained below, this distinction may be important where the impacts of acid deposition lead to changes in the price of the affected resource or commodity.

Second, market prices used to estimate changes in costs and revenues from the resource owner's perspective may not reflect true resource costs, which is the appropriate measure from the perspective of society at large.[1] Possible adjustments to market prices -- commonly referred to as "shadow pricing" -- would account for taxes, subsidies, monopoly profit, and underemployed resources.

Third, the choice of discount rate used to translate future impacts into present value terms may differ. Conventional wisdom, supported by a fairly wide body of literature, holds that private (e.g., the resource owner's or producer's) and societal discount rates will differ due to market imperfections and distinct influencing factors. From the resource owner's perspective, the appropriate discount rate is the rate at which the resource owner may shift funds between time periods; that is, the market rate of interest. The appropriate discount rate, therefore, would be approximated by the corporate bond yield or commercial bank prime rate, adjusted for inflation. The choice of an appropriate social discount rate is significantly more complex in that there is considerable uncertainty in specifying a particular rate. In practice, a range of social discount rates are tried (e.g., 5%, 10%, 15% as recommended in Treasury Board, 1976) to test the sensitivity of results. In environmental issues, a zero discount rate should also be tried for purposes of comparison (Page, 1977).

Some resources and goods that may be affected by acid deposition have no markets, although they do have value to society. Among these are wilderness resources, aesthetics (e.g., scenic views), avoidance of pain and suffering from disease, and unique environmental features. The effect of acid deposition on the enjoyment or use of non-marketed resources are called **amenity impacts.**

Amenity values include resources or goods whose direct use does not capture their full value. For example, it is likely that the people of Ontario value the preservation of Canada's forest lands over and above the commercial value of those stands. Preservation values might be held by both present and future users and non-users of the resource. Preservation values include:

- Option values -- the value over and above the value from the direct use of the resource (called "exchange value") which a person places on the option of using the resource in the future.

- Existence value -- the value over and above the exchange value and option value which a person places on the continuing existence of the resource for the benefit of future generations.

Amenity values also include other "intangible effects, features, and consequences which people consider necessary to social, economic, and ecological well-being, as well as those which might otherwise be considered luxuries" (Donnan, 1986).

In the absence of observable market prices, quantities, and costs related to amenity values, measurement of the impacts on these resources require other techniques. These techniques fall into two major groups:

- imputed market approaches; and
- non-market approaches.

Imputed market approaches rely on surrogate markets related to the resources in question. Examples include assessing the impact of acid deposition on recreation sites through changes in property values or relating payments on life insurance premiums to the perceived value of life. Non-market approaches involve direct inquiry of individuals about the perceived value for a good or service. For some amenity values, such as existence or option values, direct survey is the only possible estimation technique.

Distributional and social consequences of acid deposition include effects that are not captured by financial or amenity impacts. They include the effects on economic activity (as measured by employment and personal income), the distribution of impacts across groups in society, the impacts of changes in the resource base for single industry towns, with any associated dislocation and social upheaval.

B.2 Impacts Addressed in the MOE Model

Exhibit B.1 summarizes the possible frameworks for valuing

EXHIBIT B.1: POSSIBLE VALUATION FRAMEWORKS FOR IMPACTS OF ACID DEPOSITION

		PRIVATE	PUBLIC
FINANCIAL IMPACTS	Resource Owner Perspective	not applicable (emittors experience little or no change in revenue or costs from acid deposition)	- change in revenues, costs (calculated with a market discount rate)
	Societal Perspective		- change in revenues, costs (shadow priced) - change in consumer welfare - calculated with a social discount rate
AMENITY VALUES		not applicable	- non-marketed values - intangibles - preservation (option and existence) values
DISTRIBUTION AND SOCIAL CONSEQUENCES		not applicable	- e.g., employment, community dependence, dislocation

the impacts of acid deposition, as outlined in the previous section.

The 1980 models measure public financial impacts. Documentation of the models does not explicitly identify whether these costs have been estimated from the perspective of the resource owner or from the perspective of society at large. Present value calculations are based on a discount rate of 5%, which is consistent with Treasury Board's recommendation for a lower-bound value of the social discount rate. Effects on consumers (i.e., changes in consumer surplus) have not been calculated as the model assumes no price changes will occur as a result of acid deposition. Finally, market values have not been shadow priced (i.e., adjusted to reflect true resource costs), possibly because this process significantly complicates the calculations and requires a substantial amount of data. The 1980 model could be considered a valuation of the public financial impacts of acid deposition as measured from the perspective of society at large under the assumptions that:

- all prices are constant; and
- market values adequately reflect resource values.

Recommendation: It is recommended that the current public financial impact framework be maintained and that these impacts be calculated from the perspective of society at large. This approach requires estimates of effects on consumers as well as producers. It is not recommended that market values be shadow priced, as this would not be cost effective.[2]

Recommendation: Distributional and social consequences are often important criteria in evaluating government actions or projects. For this reason, it is recommended that key distributional and/or social impact indicators be considered for inclusion in the model.

Two major indicators would be employment and identification of single industry communities. Identification of dependent communities requires an analysis of the economic structure of each community. Employment impacts can, however, be calculated from aggregate industry data and output from the 1980 model. Information on an important impact indicator could, therefore, be provided at a small marginal cost to MOE. Other distributional/social indicators are impacts on personal income and tax revenues. Impacts on personal income will be reflected in employment data; estimation of tax revenues requires a detailed analysis of profitability and marginal tax rates. Estimation of these two indicators is not considered cost-effective for the MOE models.

Recommendation: It is recommended that employment impacts be estimated and included in the model output.

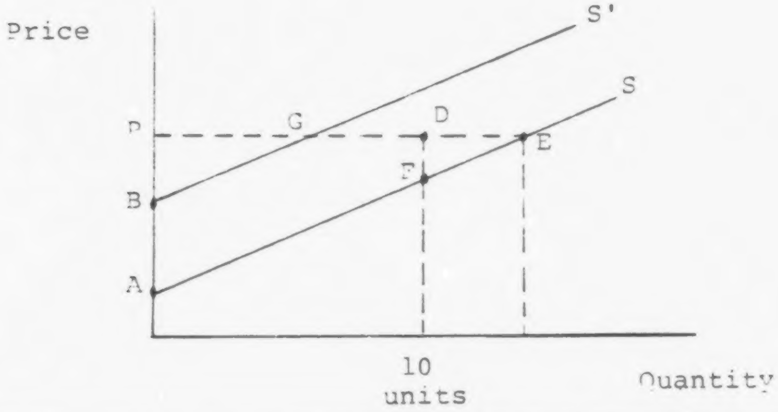
B.3 Measures of Economic Welfare

The preceding section recommends that the models maintain the public financial impact framework, where impacts are measured from the perspective of society at large. The technical term for these impacts is "economic welfare." The value of gains or losses in economic welfare are defined and measured by changes in producer and consumer surplus. Producer and consumer surplus are explained below.

Producer surplus is defined as the amount the producer receives for a good over and above the minimum cost of supplying it. It is given as the distance between the supply and the price curves or, in Exhibit B.2, the distance DF at 10 units. Total producer surplus is the sum of corresponding distances for each unit produced or, in Exhibit B.2, the area APE.

Where acid deposition leads to an increase in costs for the same amount produced (and/or a decrease in the amount produced for a given cost) with no offsetting increases in market price, total producer surplus falls. This is illustrated by a leftward shift in the supply curve from S to S' and the associated shrinking of the producer surplus to the area BPG in Exhibit B.2. The financial cost to the producer is the difference in producer surplus with and without acid deposition or, in our example, the area ABGE.

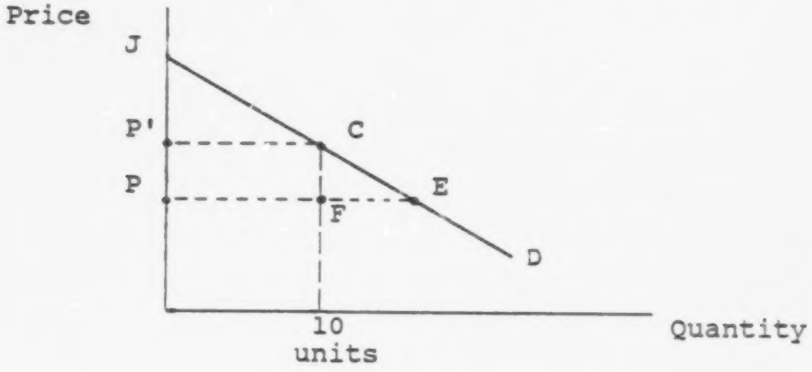
EXHIBIT B.2: PRODUCER SURPLUS



Consumer surplus is defined as the difference between the maximum amount a person is willing to pay for a commodity and the prevailing price. This is shown in Exhibit B.3 as the distance CF for 10 units. Total consumer surplus (analogous to producer surplus) is the sum of the corresponding distances for each unit produced or the area PJE.

In general, acid deposition is not likely to change tastes or the demand for a product; that is, the demand curve is not likely to shift. However, total quantity demanded, and more importantly, consumer surplus will be affected if prices change. In Exhibit B.3, a price increase from P to P' will reduce total consumer surplus to P'JC. The loss in consumer surplus corresponds to the area PP'CE.

EXHIBIT B.3: CONSUMER SURPLUS

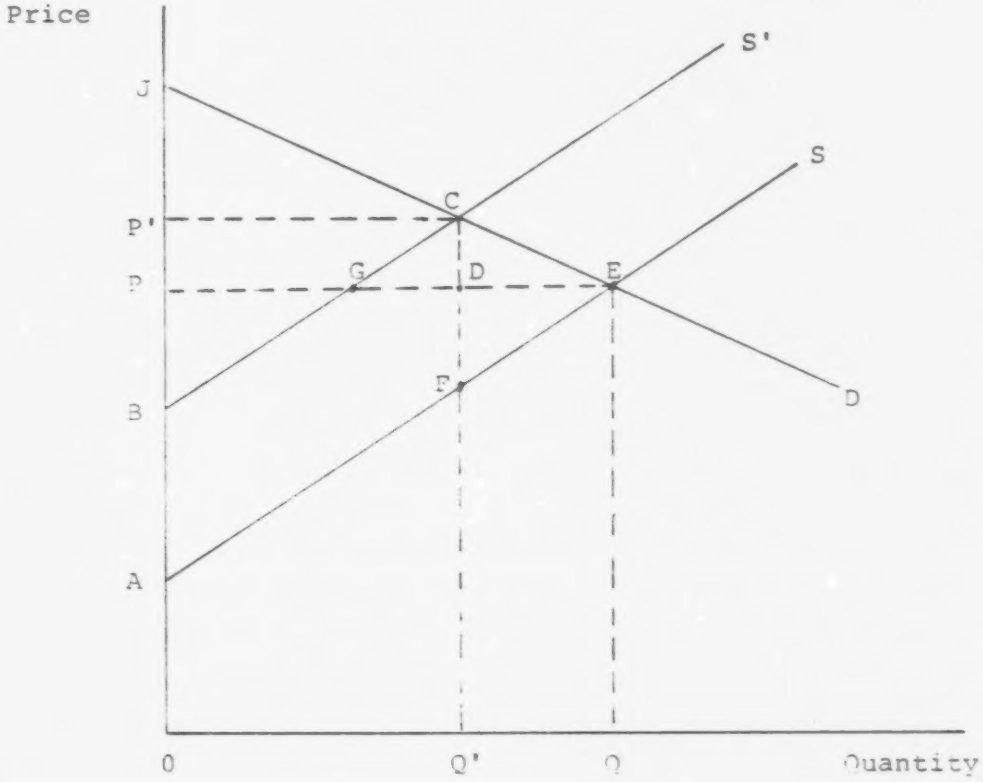


The possible impact of acid deposition on producer and consumer surplus jointly is illustrated in Exhibit B.4. In this illustration, acid deposition is assumed to reduce production levels for a given cost (i.e., the supply curve shifts from S to S'). This shift increases the equilibrium price (i.e., the price at which demand equals supply in the market) from P to P'.

The original consumer surplus is shown by the area PJE (in Exhibit B.4); the new consumer surplus is the smaller area P'JC. The loss in consumer surplus is PP'CE. The original producer surplus is shown by the area APE; the new producer surplus, taking into account the shift in the supply curve and the higher price, is shown as the area BP'C. The change in producer surplus is the difference between these two areas. The magnitude of the difference will depend on the extent to which the higher price and, therefore, additional revenue on each unit (P'-P) offsets higher costs and lower volume; that is, the extent to which producers are able to pass on the effects of acid deposition to consumers.

The welfare change to society is the sum of the following areas in Exhibit B.4:

EXHIBIT B.4: PRODUCER AND CONSUMER SURPLUS


Price
J
P'
P
B
A
S'
S
C
G
D
E
F
D
0
Q'
Q
Quantity

$-$ PP'CE (loss in consumer surplus)
$-$ APE (loss in producer surplus)
$+$ BP'C (gain in producer surplus)

The resulting area ABCE is the correct measure of welfare change due to acid deposition.

There are two methods by which changes in economic welfare may be measured. The first requires knowledge about demand and supply functions, as well as shifts in supply functions and changes in quantities produced as a result of acid deposition. By modelling supply and demand functions, the analyst is able to simulate responses of both producers and consumers. Producer and consumer surpluses with and without acid deposition can then be explicitly calculated and compared. NAPAP in the United States used this approach in their 1985 Assessment by accessing various (previously developed) sectoral models. A review of similar Canadian models (see Appendix C) suggests that the necessary information is not available and/or cannot defensibly be integrated into the MOE models.

Alternatively, changes in economic welfare may be measured from price and demand information using the following equation:

$$\text{Change in economic welfare} = P(Q'-Q) + (TC-TC') + .5(P'-P)(Q'-Q) \qquad \text{(B1)}$$

where P is the initial unit price
Q', Q are the volumes demanded/produced with and without acid deposition, respectively
TC', TC are total costs of production with and without acid deposition, respectively
P' is the new price associated with Q'.

The relationship of this equation to the area ABCE in Exhibit B.4 is:

equation	**equivalent area(s)**	
$P(Q'-Q)$	$-\ Q'DEQ$	$-\ DFE - Q'FEQ$
$+\ TC-TC'$	$+\ OAEQ - OBCQ'$	$+\ Q'FEQ - ABCF$
$+\ .5(P'-P)(Q'-Q)$	$-\ DCE$	$\underline{-\ DCE}$
		$= -\ ABCE$ (i.e., loss in economic welfare)

The importance of the third term, $.5(P'-P)(Q'-Q)$, depends on price sensitivity of the market. Where prices are not affected by changes in quantity produced, this last term is eliminated. Conditions under which prices will likely not change include:

- institutionally controlled prices (e.g., marketing boards);
- small (e.g., less than 5%) changes in quantity;
- international or large markets where changes in domestic production are small relative to total quantity produced (i.e., producers face a perfectly elastic demand curve).[3]

Data required to calculate the change in economic welfare are:

- initial conditions (P,Q);
- total or average costs with and without acid deposition; and
- an estimate of the new price P'.

The first two data elements are available from initial conditions and/or biophysical impact information.

The disequilibrium price P' can be calculated from an estimate of the (own price) elasticity of demand.[4]

Equation (B1) is a general formula for estimating the change in economic welfare. Under specific conditions and assumptions, this formula may be simplified. Appropriate changes to the formula for the assumptions embodied in the 1980 MOE models are discussed in Sections 3.3.3 and 4.3.3 of the text for forestry and agriculture, respectively.

B.4 Substitution

The measure of changes in economic welfare discussed above do not consider the possibility of behavioural responses to mitigate or avoid econimic efforts of acid deposition. The measures do not, for example, take into account substitution of hardier crop varieties or biogenetic engineering as alternatives to sensitive agricultural products.

By excluding substitution, the measures discussed above will tend to overestimate economic impacts.

FOOTNOTES

1. True resource costs refer to the "opportunity cost" of a resource. Opportunity costs define costs in terms of the value of the best alternative use of the resources which must be foregone.

2. Shadow pricing is not likely to be cost-effective in this context because:
   - it would require information on component costs of production;
   - it would suggest a degree of precision not warranted by other estimates in the model; and
   - the appropriate shadow prices may change over the long time horizon used to calculate impacts.

3. The third term, .5 (P'-P) (Q'-Q), measures the area DCE in Exhibit B.4 where demand and supply curves are linear. It gives an approximate measure of the area DCE when demand and supply curves are non-linear.

4. The (own price) elasticity of demand, (e) is defined as:

$$e = \frac{\text{percentage change in quantity}}{\text{percentage change in price}}$$

$$= \frac{\Delta Q}{Q} \; \frac{P}{\Delta P}$$

As noted, Q', Q, and P are available from initial conditions and/or biophysical impact information. Therefore, P' can be calculated as:

$$\text{percentage change in price} = \frac{\text{percentage change in quantity}}{e}$$

$$\Delta P = \frac{\Delta Q}{Q} \; \frac{P}{e}$$

$$\text{and } P' = P + \Delta P$$

APPENDIX C

REVIEW OF CANADIAN ECONOMIC MODELS

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REVIEW OF CANADIAN ECONOMIC MODELS

This appendix presents a review of existing economic models along with related studies and data sets. The purpose of the review is to identify whether the models can be used to improve the economic valuation of impacts in the MOE computer models used to estimate the biophysical consequences of acid deposition. The focus is on two sectors: agriculture and forestry.

The 1980 MOE models calculate the financial cost of acid deposition as a constant price multiplied by the change in output or yield, or as a change in production costs. The financial value of acid deposition is estimated using forecasts of production in the absence of acid deposition. The production forecasts (in physical units) are based on extrapolations of past growth rates. Extrapolations for agriculture and forestry are based on different years: agricultural forecasts use production statistics for 1971 to 1979; forestry forecasts use statistics for 1940 to 1966. Production forecasts in physical units are translated into economic values by applying forecasts of prices. Prices remain constant in the absence of acid deposition and the same set of constant prices is used to value production with acid deposition.

Existing models are reviewed in this appendix in terms of the following criteria:

1. The ability to provide defensible production forecasts in physical units, as well as forecasts of prices and demand (price times quantity) in the absence of acid deposition.

2. The ability to provide information on demand elasticities (to allow predictions of price changes in response to changes in supply).

3. The ability to provide information on the position and shape of the supply curve (supply elasticities).

4. The ability to relate biological factors to the cost of production and the quantity supplied (specification of production and supply functions).

5. The ability to assist in calculating consumer and producer surpluses. (Criteria 2 through 5 require modelling of demand and supply functions.)

6. The extent to which the model uses the best available data.

7. The ability to extract model coefficients or to be linked or integrated with the MOE acid deposition models.

8. The ability to provide simulation runs separate from those provided by the MOE models in order to assist in identifying the economic effects of acid deposition.

The review of each model begins with a brief description. The interested reader is referred to the bibliography at the end of the appendix for more information on model purpose and structure. Only one macro-econometric model is reviewed. The remaining models are simulation models or models specific to forestry or agriculture.

CANDIDE AND OTHER MACRO MODELS

The Candide model, developed by the Economic Council of Canada (Economic Council of Canada, 1985; McCracken, 1973; Zucker & Rao, Economic Council of Canada, personal communication), is a general purpose model that represents most of the major aggregates in Statistics Canada publications used by government departments for policy analysis. Because of its general orientation and the incorporation of some industry detail, Candide is much larger than most econometric models, with 2390 endogenous variables, 825 stochastic equations and 1050 endogenous inputs. Expenditure categories are substantially disaggregated. The 170 or so final demand categories are converted into commodity requirements for use in an input-output submodel. The final demand categories are converted, using the input-output tables, into industry outputs which are used simultaneously throughout the model. The input-output tables are also used in the price submodel for converting industry and import prices into final demand prices.

The current version of Candide used by the Economic Council of Canada is Candide model 3.0. It is estimated using time-series data from 1954-81 and uses the 1979 input-output table. Candide model 3.0 can be viewed as a collection of 44 well-articulated industry models, carefully interfaced with a traditional neo-Keynesian macro-economic model. Even though Candide model 3.0 is based on the IS-LM framework, it incorporates most of the recent developments in macro-economics: government budget constraints, expectations, reaction functions, flexible exchange rate, rounding out, vertical Phillips Curve, supply constraints and so on.

Although Candide contains some industry detail, the agriculture and forestry sectors are handled as single, homogeneous industries. Therefore, no forecasts are available for subsectors within each industry. Because the model is demand-led and macroeconomic in orientation, it does not provide information on the shape or slope of demand and supply functions (criteria 2 through 5 above). Candide's usefulness in the present exercise, therefore, is limited to providing national forecasts of demand, output, and prices for agriculture and forestry. Candide does not provide disaggregation beyond the national level.

Because Candide's forecasts are provided by a macro model (and therefore take account of expected changes in population, employment, GNP, and technology), they can be used as benchmarks to modify forecasts provided by sector-specific, more disaggregated models. This technique represents an improvement over extrapolating past growth rates and assuming constant prices through time.

Two macro-economic models developed from the original Candide model of the Council are available from Informetrica, an Ottawa based consulting firm. The two models are called TIM, which is a national econometric model, and RIM (Regional Informetrica Model). RIM provides output for each of the ten provinces and both territories and develops projections to the year 2005 on an annual basis. The model is a long run model and is designed to examine trends in the economy as opposed to turning point variations within a calendar year. RIM generates output for up to 60 industries (depending on the province), approximately to the two digit SIC code level. The service sectors are not as finely broken down as the manufacturing sectors. The RIM model develops its provincial projections largely in a top-down manner. Projections for the provinces are constrained so that the sum of the provincial projections do not exceed the forecasted national totals.

Candide and RIM projections should be relatively accessible. RIM simulations are actively marketed by Informetrica. MOE may wish to hold further discussions with Informetrica or the

Council to identify whether agriculture and forestry forecasts from Candide or RIM could be tailored to meet the needs of the MOE model.

To the best of our knowledge, Candide and RIM provide more industry detail than any other macro models in Canada. Even with this detail, the two models satisfy only one or two of the MOE model requirements. For this reason, no other macro-econometric models were reviewed in detail as part of this exercise. However, some discussions were held on the Conference Board models (Conference Board of Canada, 1983; Cady & Rheaume, Conference Board of Canada, personal communication).

The Conference Board's national macro-economic model, called Medium Term Forecasting Model, provides quarterly forecasts for up to 5 years but can provide projections for a longer period as long as the user can provide values for the exogenous variables (which number better than 1000). The model includes 40 industries and provides separate forecasts for agriculture and forestry. The national model is part of a system of models which encompasses essentially separate macro-economic models for each province.

The provincial models, called the Provincial Medium Term Forecasting Models (PMTFM), embody essentially the same industry detail as the national model and provide provincial forecasts which add up to the national aggregates. Therefore, like Informetrica's RIM model, the Conference Board model offers the advantage of providing separate forecasts for Ontario agriculture and forestry. Moreover, the Conference Board model appears to be less "top-down" than the RIM model. Once the national exogenous variables are input to the provincial model, each province has its own behavioural equations that result in provincial projections. It appears that there is some simultaneity in the model that allows adjustments for provincial shares. (This impression must be confirmed through direct discussion with the two organizations.) If projections past five years are needed, the user needs to provide values for the exogenous variables.

SERF (1986)

The Socio-Economic Resource Framework, or SERF, was developed by the Structural Analysis Division of Statistics Canada. It represents a new generation of the input-output models that have been the focus of the Division's program since it was established in 1973 (Hamilton et al., 1983; Hoffman, 1983; Statistics Canada, 1986; Hamilton, Statistics Canada, personal communication).

SERF is a computer based decision support system consisting of a family of models that can be used to simulate time structured scenarios of possible evolution paths of the Canadian economy and to identify sources of tension between the availability of and requirements for resources. Emphasis is placed on modelling the flows of materials and energy that are required to meet human needs and the processes that transform raw materials into finished goods.

To the extent possible, flows and stocks are measured in physical quantity units, and transformations are represented as relationships between input flows and output flows in such a way that mass and energy principles are maintained. The concept of tension provides for disequilibrium between supplies of resources, energy, and labour, and the requirements for them.

The strategy underlying the design of SERF is to link physical transformation processes uni-directionally only through the system as a whole. Strong feedbacks among processes are localized. This strategy assures some consistency among components, but the lack of feedback from downstream processes to upstream processes can result in tensions or lack of consistency among components. The block recursive mathematical structure of SERF distinguishes it from macro-econometric models which are time recursive.

SERF consists of four blocks of physical transformation components. The demography component represents the basic demographic processes of population dynamics, household formation, and labour force participation.

The consumption component represents the infrastructure that yields services required by society. It calculates the flows of goods, services, energy, and labour required to put infrastructure in place and to operate it. Emphasis is on the availability of stocks, not on measurements of the value of the flows. The household consumables subcomponent of the consumption component represents the use of goods by individual consumers on a flow basis. Items such as food and clothing are treated on a per capita basis, using age group, sex differentiated per capita coefficients. Other items are treated on a per household basis.

The fabrication and assembly component represents the processes that transform materials and primary energy into finished goods required by both the consumption and extraction components. It can also represent processes that transform waste flows into environmentally benign materials or reusable materials and energy. The underlying concepts are the Koopman's activity analysis and Leontief's input-output models.

The material resources component represents the activities of exploration, extraction, and refining non-renewable resources as well as the management and harvesting of renewable resources. For renewable resources such as forestry, additions to the stock of producible reserves are the result of growth; growth may be enhanced by forest management activities, but may be retarded by pollutants resulting from human activity. Land use and the evolution of land characteristics such as soil quantity and quality are accounted for in this component.

The material resources component consists of five subcomponents: primary energy, minerals, forest products, agriculture, and fish and wildlife. All of the subcomponents are supply driven in that planned production or capacity to produce are the main exogenous variables and are intended to reflect resource endowments. The planned harvest is the driving variable for forestry; models representing forest inventory and forest biodynamics have been developed, but not implemented. The agricultural subcomponent distinguishes livestock from land based crop activities. The driving variable is planned production. More elaborate models are being designed and implemented for both agricultural activities, including a land based crop model which keeps track of agricultural land use and the evolution of soil quality. Although the material resource subcomponents in SERF are in early stages of development, the subcomponent structure is viewed by the SERF developers as an appropriate framework for accommodating other models as they are developed.

Our review suggests that SERF will be of limited use in refining the MOE model. SERF does not generate its own forecasts and projections, and therefore cannot be used for demand projections. SERF is physically based, and therefore incorporates no data on prices, costs, or elasticities. Demand for consumables, for example, is determined by per capita coefficients. However, once the material resources subcomponents are further developed, SERF could be used to simulate scenarios of the effects of acid rain on forestry, agriculture, and other sectors.

SERF is relatively accessible. The framework is operated commercially at the University of Waterloo. DPA recommends that the development of SERF be monitored closely by MOE staff. SERF II should be available in less than a year. For the time being, however, SERF's direct applicability to the MOE model is limited.

FORCYTE (1983)

The Forest Nutrient Cycling and Yield Trend Evaluator (FORCYTE) is a forest management simulator designed to estimate the long term consequences of intensification of forest management for biomass yield, site nutrient capital, and the economic performance and energy benefit/cost ratio of management. The model was developed at the University of British Columbia and can be accessed through the UBC computer system (Kimmins, 1985; H. Kimmins, University of BC, personal communication).

Designed originally to examine the biological consequences of biomass for energy programs in forestry, the model has evolved into a more general forest management simulator. FORCYTE can be used to produce species and site specific simulated managed stand yield tables for a variety of management scenarios, including initial planting density, spacing and thinning, fertilization and utilization regimes, and various rotation lengths.

Because of the shortcomings of both empirical and process models, there was a need for a hybrid model -- a model that included the predictive attributes of traditional empirical models, along with the ability to simulate the effects of management on the processes that determine forest growth. FORCYTE simulates the accumulation of biomass in a forest community over time, with feedback between simulated nutrient availability and biomass.

The model consists of two programs run sequentially. The first program is an empirical yield model that uses Chapman-Richards growth equations fitted to data on the accumulation of tree stem volume, and on shrub and herb shoot biomass over time. The resultant data on biomass accummulation, litterfall, and natural mortality are used to calculate total net annual primary production for the herbs, shrubs, and trees. The increment data are subsequently used as the driving function for the second program.

The second program uses the array of increment data as a driving function to simulate biomass accumulation. The program also simulates the three major pathways of nutrient cycling -- geochemical, biogeochemical, and biochemical. The latter forms the basis for a simulation of soil nutrient availability, which is used as a modulator of the basic empirical patterns of forest growth provided by the first program.

At the start of a run, the user must identify the initial condition of the simulated ecosystem, including the desired management scenario. The latter includes the economic and energy costs of all proposed management interventions, the economic and energy benefits of all harvested materials, and the planting, spacing, thinning, fertilization, utilization, and rotation length conditions to be used in the run.

Simulations produced by the model suggest that, in terms of total biomass production, the 60-year rotation with complete tree utilization, heavy thinnings, and heavy fertilization provide the best performance. Production is especially sensitive to fertilizer treatments.

Because FORCYTE focuses on production and supply, it cannot provide production forecasts and information on the shape of the demand function (criteria 1 and 2 in the Introduction). The model could, however, be helpful in determining the shape of the supply curve for different forest species in the absence of acid rain and the extent to which the supply curve shifts inward because of the above-ground and below-ground effects of acid deposition. Because the model is ecologically based and includes an economics package, FORCYTE could also be useful in determining links between biological factors, physical production, and the cost of production (at different volumes with and without acid deposition).

Because of FORCYTE's structure, it is doubtful that equations or components of FORCYTE could be used unchanged in the MOE model. A more likely approach would be to use output from simulation runs to develop relevant equations for the MOE model. This approach must be explored in more detail with UBC staff responsible for operating the FORCYTE model.

MODIFIED TIMBER RAM MODEL

This model is described in Walker & Lougheed (1985). The report provides a description of how a quantitative timber management planning model was used to design strategies for the management of a 195,000 ha New Brunswick forest of mixed public and private ownership. Forest managers were concerned about the possibility of a future wood fibre shortage in the area and needed a method to examine the nature of this possible shortage in terms of their relative preferences for achieving higher harvest volumes versus lower management costs. This need was met through the development of a set of timber management strategies which defined alternative harvest volume/minimum production cost compromises.

The area's forest structure, alternative stand level regimes, forest management preferences, and government planning requirements were expressed as a series of stand management alternatives, objectives, and constraints within a modified version of the Timber Resources Allocation Method (Timber RAM) model. The linear programming problems defined in the model contained 3,700 variables and 108 constraint functions. The model results indicated the maximum volume obtainable from the district forest, the minimum production cost for achieving the harvest level, and the minimum-cost strategies for achieving progressively lower harvest levels. The model results show that a 477 percent increase in harvest level can be achieved for a 12 percent increase in average production cost. The model also indicates substantial differences among the associated timber management strategies.

The report suggests that, because the modified Timber RAM model contains virtually no data except that provided by users, the model may be readily applied to other forest areas and other forest questions. The implications for MOE, however, are that no equations from the RAM model could be added unchanged to the MOE model and the specification of equations appropriate to the MOE model would have to be preceded by substantial data collection. The required amount of data assembly may be beyond the scope of the MOE modelling exercise.

Alternatively, simulation runs from this version of Timber RAM or other versions used in British Columbia, Alberta, and Saskatchewan could provide information and test hypotheses on the shape and position of production and supply functions, and the responses of production and supply functions to the above-ground and soil impacts of acid deposition. The model would not provide any information on production forecasts or demand functions.

FEPA

FEPA stands for the Forestry Economics and Policy Analysis Project operated at the University of British Columbia.

The objectives of the project, supported mainly by the Canadian Forestry Service, include research and post-graduate education in analytical techniques. The core of FEPA's research activity is the development of a set of integrated, computer based analytical models for investigating the dynamics of Canada's forest sector. The models are designed to identify patterns of change in resource supplies, manufacturing and markets, and to demonstrate the consequences of alternative governmental and industrial policies. The research program also includes a variety of special applications that complement the modelling effort.

The models currently operated by the project were largely developed over a twenty year period by American researchers and are designed to provide a comprehensive picture of the U.S. forest products industry. Most of these models are concerned with markets and trade and therefore contain price and income elasticities that could be used to identify the shape and position of forest product demand functions. Our contact indicated the supply functions are more rudimentary as their main purpose is to model the economic dimensions of the forest resource. Nonetheless, the material we reviewed indicated the FEPA models could also provide some information on supply elasticities.

DPA reviewed two models used by FEPA (Lekawski & Nilsson, 1985; Phelps, 1984; Uhler, 1985; D. Williams, FEPA, personal communication). The Timber Assessment Market Model (TAMM) is a spatial market equilibrium model designed to determine regional prices and trade flows in softwood lumber and plywood in several geographical regions in North America. Canada is considered as a single region which is a net supplier of softwood lumber to the other regions. In TAMM, Canadian softwood lumber exports to the United States depend on the profit margin (price minus cost) and industry capacity. A Canadian version of TAMM has been developed by FEPA but a comprehensive Canadian data base does not yet exist. Therefore, the original U.S. model in its unmodified form is currently being used by FEPA in the project's policy analysis.

The Pulp and Paper market model is a price endogenous linear programming model, designed in the United States to analyze the dynamics of pulp and paper supply and demand in North America. Similar to TAMM, a Canadian version of this model has been developed by FEPA but a comprehensive data base for Canada does not yet exist. Therefore, the original U.S. version is being used by FEPA in its policy analysis.

Until the Canadian versions of these models are fully operable, MOE will need to address the question of whether demand and supply elasticities developed from the U.S. data can be used in a Canadian model. Our current thinking is that U.S. based elasticities could be used in the absence of Canadian based parameters, but this hypothesis requires more detailed investigation.

Consumer Demand for Major Foods in Canada (Hassan & Johnson,1976)

The purpose of this study was to provide estimates of the consumer demand for food commodities. Subsidiary objectives were:

- to provide a review of modern demand theory
- to provide estimates of elasticities for major food products
- to present a full system of demand parameters for food
- to provide an assessment of the policy implications of the full demand system and to indicate possible methods of using such estimates in forecasting and decision-making.

The study provides a full system of price and income elasticity estimates for 27 foods. It also provides cross-price elasticity estimates, a synthesis and comparison of these estimates with others available for the US and Canada, and a section devoted to the development of an integrated framework for using the estimates in projections and policy analysis. The results cover the following sectors: meats and poultry, dairy products, fats and oils, fish, eggs, cereals, beverages, sugar, fruits and vegetables, and other foods.

Demand functions are estimated for 27 food commodities using 1950-1972 data from Statistics Canada. The quantity demanded of a specific commodity is seen as a function of per capita disposable income (in current dollars), the price of the commodity, and the prices of other (related) commodities.

Prices are considered explanatory variables in the model specification. The authors admit this involves a limiting assumption. In most ad hoc empirical investigations of markets, prices and quantities are usually structured as jointly determined variables. For the current specification, it is assumed the locus of equilibrium points, conditioned by other prices and income, traces out a demand function. This specification is rationalized on the basis of the importance of government programs in shifting supply, the influence of the larger US market in determining prices of food commodities, and the fact that Canada is a heavy participant in the international market for foodstuffs.

Of particular interest to the MOE model are the three demand equations for cereals, fresh fruits, and canned fruits. Although the model builders were unable to develop satisfactory equations for fresh and canned vegetables, the study does report direct price elasticities for fresh and processed vegetables from a previous study. These elasticities were used to construct the demand model.

Study results include the direct price elasticity, income elasticity, and expenditure share for each of 27 food commodities in the demand matrix, plus the cross-price elasticities between the 27 food commodities (incorporated into an elasticity matrix for food and non-food commodity groups).

The results from this study could be helpful in refining the MOE model. The income, direct price and cross-price elasticities could be used to determine the shape and position of the demand curves for agricultural commodities included in the MOE model. Combined with income and population forecasts from other models (e.g., Candide, SERF, and the demographic models of Statistics Canada), these parameters could also be used to develop production and demand projections.

The demand model developed in the study also has some serious limitations. The equations are developed for highly aggregated commodity groups, not for the specific categories included in the MOE model. It is not clear to what extent these highly aggregated results can be applied to the MOE categories. The fruit category and the grain and forage greens category under the MOE model may correspond fairly well to the cereals and fresh fruit groupings in the study, but the MOE model encompasses six vegetable and related categories compared to one grouping (fresh vegetables) in the Consumer Demand study. As well, this study does not include any non-food agricultural products such as tobacco which are very important to Ontario agriculture.

Another concern is that the equations are estimated from 1950-1972 data. Whether statistical relationships estimated from this period are relevant today can be questioned. Finally, the study provides no information on the shape and position of supply functions.

FOOD AND AGRICULTURE REGIONAL MODEL (FARM)

The FARM model is a quarterly forecasting model used by Agriculture Canada (Agriculture Canada, February 1983 and March 1983). The model contains both demand and supply functions for 15 commodities in four groups:

- livestock
- grains and oilseeds
- dairy products
- poultry and eggs.

Our review of the model indicated a number of limitations for use in refining the MOE model. Most importantly, the model covers very few of the specific food categories included in the MOE model. The only area of overlap is in the grains and oilseeds component.

Additional problems were uncovered in a telephone interview with the Agriculture Canada official responsible for the model:

- The demand and supply coefficients are estimated from a database with 1976 as the terminal year. Demand/supply conditions may have changed substantially since then.

- The model is designed for short term forecasting, and thus the demand coefficients are probably inappropriate for long term projections or for assessing the price effects of long term shifts in the supply function.

One area in which FARM might be helpful is in the assessment of the shape and position of supply functions. The supply functions in FARM for the crops most similar to those in the MOE model (e.g., grains and oilseeds) could be analyzed to see whether the specification of and coefficients from the supply equations could provide some insights. This approach is recommended only if information on specific crops in the MOE model is not uncovered from another source.

CONCLUSIONS

Exhibit I shows the eight models summarized in this appendix rated on a five-point scale according to the eight criteria listed in the Introduction. The five-point scale is as follows:

H = High probability that the model can assist in refining the MOE model.

M = Some possibility the model can assist in refining the MOE model, but more investigation is required.

L = Limited likelihood (or no potential) that the model can assist in refining the MOE model.

U = Properties of the model in relation to this criterion are unknown.

NA = Not applicable.

The results from this review are not encouraging. None of the models possesses blocks of equations that can be used without modification in the MOE model. In virtually all instances, the information from these models takes the following forms:

- individual coefficients and equations that could be used to develop similar equations for the MOE model
- simulation runs that could be used to identify the shape and position of supply and demand functions and possible effects of acid rain on the position of supply functions
- independent simulations of the effects of acid rain
- aggregate production, demand, and price forecasts that could be used as control variables on more disaggregated forecasts from less sophisticated models.

Other limitations are that some of the more useful

EXHIBIT I: RATING MODELS ON EIGHT CRITERIA

Criteria	Candide	RIM	SERF	FORCYTE	NB Forest	FEPA	Consumer Demand	FARM
Production, Demand, & Price Forecasts	H	H	L	L	L	H	H	M
Demand Elasticities	L	L	L	L	L	H	H	M
Supply Elasticities	L	L	M[1]	H	H	M	L	M
Relate Biological Factors	L	L	M[1]	H	H	L	L	M
Calculate Producer and Consumer Surpluses	L	L	L	M	M	M	M	M
Up-to-Date Data	M	M	H	NA[2]	NA[2]	U	L	L
Accessibility	H	H	H	M	M	M	H	H
Separate Simulations	M	M	M	M	M	U	L	L

[1] Only after further development of SERF.

[2] User must supply the data.

agricultural models are out of date and no single model can provide useful information on producer and consumer surpluses. This is because models are either demand led or supply oriented. To estimate possible effects on producer and consumer surpluses, MOE must collect and compare information, coefficients, and outputs from different models.

The final concern is that information on supply functions for agriculture appears to be limited. The arguments contained in the Consumer Demand study of Agriculture Canada regarding food supply in this country may offer some guidance in looking at supply functions for the MOE model.

We suggest the following steps may hold the most promise:

(1) Use the national forecasts of production, demand, and prices from Candide or RIM as controls on forestry and agriculture forecasts for specific categories and/or investigate whether the Ontario forecasts from RIM or the Conference Board can be used directly in the MOE model. More detailed forecasts could be developed from the Consumer Demand study and FEPA.

(2) Use elasticities from the Consumer Demand study and perhaps the FARM model to assist in identifying demand functions for agricultural products.

(3) Use elasticities from FEPA to assist in identifying demand functions for forestry.

(4) Use FORCYTE, the Modified Timber RAM model and perhaps the FEPA models as sources to identify supply functions.

(5) Use Candide and SERF (the revised version) to conduct independent simulation runs on the effects of acid rain.

These steps will require detailed discussions with the people responsible for the models before the information can be incorporated into the MOE model. The final question is whether the effort needed to refine the economic evaluation techniques of the MOE model is cost effective. This question must be evaluated within the context of the reliability of the environmental data and the magnitude of the environmental impacts. The effort could be worthwhile if the quality of the environmental data is high and the magnitude of the environmental impacts is significant. If these two conditions are not satisfied, extensive refinement of the economic valuation techniques by linking up with other models should perhaps be questioned.

People Contacted in Preparing Appendix C

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APPENDIX D

ALTERNATIVE ECONOMIC VALUATION FOR FORESTRY

APPENDIX D
ALTERNATIVE ECONOMIC VALUATION FOR FORESTRY

The 1980 model assumes that acid deposition will not have any effect on the total quantity of wood extracted. It has been recommended that this assumption be maintained. However, as discussed in Section 3.3.3, the volume of wood extracted may be affected where acid deposition has a sufficiently large effect on potential yield. With changes in total quantity of wood extracted, market prices will change. Under these conditions, the simple formula TC-TC', as used in the revised model will bias estimates of changes in economic welfare due to acid deposition.

The extent of the bias arising from the simple formula is illustrated graphically in Exhibit D.1. Under the constant quantity assumption, the change in total economic welfare is the area ABHE (see Section 3.3.3). With changes in quantity and price, however, the theoretically correct measure of welfare change -- in this case welfare loss -- is the area ABCE, calculated using the general formula:

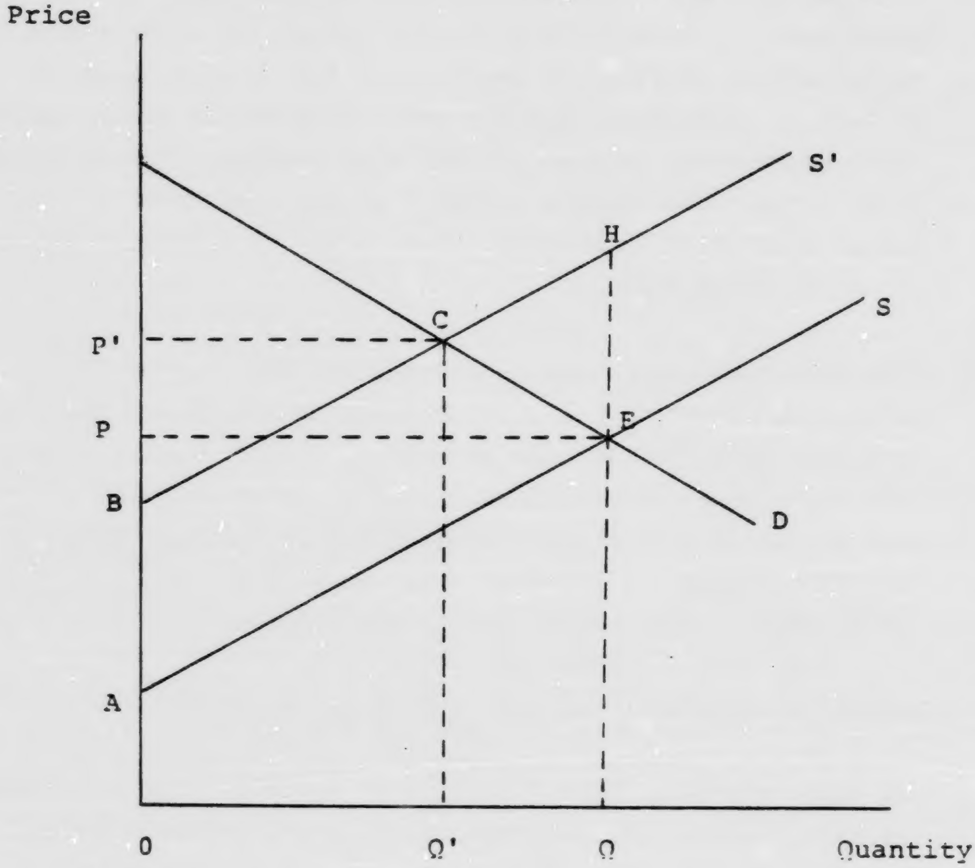
$$\text{Change in economic welfare} = P(Q'-Q) + (TC-TC') + .5(P'-P)(Q'-Q)$$

In this example, TC-TC' will overestimate the economic welfare loss to forest-related impacts of acid deposition. The magnitude of the bias will depend on the shapes of the supply and demand functions (and the values of the associated elasticities). In this example, the bias is estimated as the area CHE[2].

If changes in total quantity of wood extracted are introduced into the model, it is recommended that the formula TC-TC' be replaced with the general formula for estimating changes in economic welfare.

As discussed in Appendix A, calculation of the third component of the economic welfare formula requires an estimate of the new price P'. The new price can be

EXHIBIT D.1: CHANGES IN ECONOMIC WELFARE IN THE FOREST SECTOR



calculated using an estimate of the (own price) elasticity of demand:

$$\Delta P = \frac{\Delta Q}{Q} \; \frac{P}{\text{elasticity}}$$

$$P' = P + \Delta Q$$

A review of available Canadian models for forestry (see Appendix C) indicates that some estimates of the elasticity of demand for forest products are available. In particular, the Forestry Economics and Policy Analysis (FEPA) project at the University of British Columbia operates two forest market models. Both the Timber Assessment Market Model (TAMM) and the Pulp and Paper Market Model incorporate demand elasticity estimates which could be extracted for use in the MOE models.

There are, however, some limitations with these elasticities. First, comprehensive Canadian databases do not yet exist and U.S. estimates are used as surrogates. Second, the elasticities available from the models do not directly relate to the demand for roundwood. The TAMM model focuses on the demand for softwood lumber and plywood; the Pulp and Paper Model on that particular market. Using elasticities from the models, therefore, assumes that the price/quantity relationships are the same for forest products as for roundwood.

Based on these limitations, we suggest that any changes in economic welfare (where there are changes in quantity) be measured with and without this final welfare component. As more refined and reliable estimates of elasticity of demand for roundwood become available, more emphasis can be placed on estmates of welfare change calculated with the general formula.

FOOTNOTES

1. Changes in quantity will not always lead to changes in price. Prices will not be affected when they are institutionally controlled, or determined in an international market where Ontario's contribution to total supply is small.

2. The term .5(P'-P) (Q'-Q) measures the area CHE when demand and supply curves are linear; the term approximates the area when demand curves are non-linear.

APPENDIX E

PARTIAL LISTING OF HISTORIC BUILDINGS AND STRUCTURES IN ONTARIO

- Public Works Canada
- Environment Canada

PUBLIC WORKS CANADA

Summary Classification of Heritage Buildings, 1982

Public Works Canada

The following is a list of pre-1945 buildings owned by PWC. We are reasonably confident that we have identified all such buildings, but due to the nature of our records a few pre-1945 buildings purchased after 1945 may have escaped our notice. Since Newfoundland joined Confederation in 1949 a special research project is needed there, for which we have not found the resources.

Where buildings on the list have been examined by members of the Heritage Structures Unit, an initial classification has been given each building. When a specific project arises involving a pre-1945 building Heritage Structures should be notified; further research may then be needed to confirm or modify the initial classification.

The Public Works classification system assigns buildings to four categories defined as follows:

1. 'Important' Important buildings have high architectural and contextual value, substantial social value and some historical interest. They are of Provincial or greater significance. The exteriors of these buildings should, gradually if necessary, be conscientiously restored, and their major interior spaces should be refurbished with strong historical concern.

Important buildings are of such clear and outstanding merit that their destruction or arbitrary remodelling cannot be contemplated.. This may require the commitment of substantial resources, although pre-emptive maintenance can keep even these buildings in admirable condition at normal cost.

2. 'Preserve' Preserve buildings have at least substantial architectural and contextual value, and modest social and historical value. In some cases Preserve buildings may differ from Important buildings only in that they seem to demand freer, less historical restoration. In other cases Preserve buildings will be the sympathetic 'background' buildings of a successful urban environment, of an historical precinct appropriate for area conservation, or of an area characterized by some unique feature or the presence within it of outstanding buildings.

Preserve buildings, when due for capital investment and therefore going through the Project Delivery System, are so valuable that the Department will accept some increased comparative cost to recycle them. The exact amount will, in each case, be a matter for Executive Committee.

3. 'Maintain' Maintain buildings have modest architectural, contextual, social or historical value, sufficient to warrant their preservation on a cost-effective basis. The Maintain category is also intended to acknowledge that certain buildings are of an age and style currently so unfashionable that it is very difficult to assess their true value. The dialectic of architectural development requires each generation to hold the work of the preceding generation in undiscriminating distain. In a modern technological economy, buildings "wear out" at precisely the same time they are least understood or appreciated. Where honest introspection suggests that the value of a building is being obscured by fashion or inter-generational competition, it should be assigned to the Maintain category, deferring final judgement to a time whose prejudices are directed elsewhere.

Maintain buildings which have already entered the Project Delivery System will be creatively recycled if the cost of doing so is the same or lower than the cost of building anew. The quality of this recycling will be governed by the normal design standards of the Department.

4. 'Insignificant' Insignificant buildings have no perceptible social, contextual, architectural or historical value.

Once it has been determined that a building is Insignificant it will be treated as a non-heritage building.

In the Spring, 1982, Cabinet approved a Heritage Policy which applies to the whole Federal Government. The Policy sets up a Heritage Evaluation Review Office (HERO), which is charged with measuring the heritage value of all Federal property. Buildings more than 40 years old may be designated either "Classified" or "Recognized". "Classified" is the higher category, and contains buildings whose demolition or wanton alteration would be a gross violation of public policy; "Recognized" buildings are of sufficient status that great efforts must be made to preserve them. HERO will be fully operational in the Fall, 1982, at which time the buildings on this list will be designated under the new system. We are entirely confident that "Important" buildings will become "Classified" and that "Preserve" buildings will become "Recognized".

There are 378 buildings on this list, of which 31 are Important, 173 are Preserve, 102 are Maintain, 22 are Insignificant, and 46 are not classified, usually because they were too remote to be easily visited.

Gregory P. Utas
June, 1982

Summary Classification of Heritage Buildings, 1982

Ontario Region

We have identified 82 pre-1945 buildings in the Ontario Region, of which 9 are Important, 34 are Preserve, 26 are Maintain, 9 are Insignificant, and 4 either have not been visited or have variable classification.

Arthur, Ont.	Federal Building, George Street. 1937. Insignificant. A town with little architectural interest; a very plain, small, vaguely Art Deco post office.
Aylmer, Ont.	Old Post Office, Talbot and Centre Streets. 1913. Preserve. Building has been recycled as town offices. A pleasant variation on the Ewart Romanesque post office.
Brantford, Ont.	Federal Building, Dalhousie and Queen Streets. 1913. Preserve. A good Beaux-Arts Classical Ewart design; a major monument in its street. One of a very few still in PWC hands, and now the only one like it in Ontario.
Brighton, Ont.	Post Office, Main Street. 1939. Preserve. A remarkably pleasant little town, thoroughly Main Streetscaped. Our building, mid-block, set back and much younger than neighbours has been transformed into a node in the streetscape plan. Handicapped ramp very forceful.
Brussels, Ont.	Federal Building, Turnberry Street. 1935. Insignificant. Typical two-storey "cottage style" post office, with no special importance to the town.
Burford, Ont.	Post Office, King Street West. 1914. Preserve. Crisp, horizontal campanile-roofed variation on the Ewart post office.
Burk's Falls, Ont.	Post Office, Main Street. 1935. Preserve. A symmetrical Georgian one-storey façade in Public Works' usual manner of the time, in this case remarkably pleasant in a brown brick with yellow stone trim. The back half of the building rises to two stories to accommodate a caretaker's apartment. In 1974 the building was extended to the rear, and the interior considerably altered. The site is towards the middle of the main downtown block, and the building is set back from the street enough to accommodate Burk's Falls' memorial to the war dead. This is the only formal building in this slightly bedraggled village of 900.

Cambridge, Ont.	(Formerly Hespeller), Post Office, 74 Queen Street. 1929. Maintain. Angle corner, two-storey brick building on a steep site at the end of the old downtown, surrounded by churches, with a view to the water.
Cambridge, Ont.	(Formerly Galt), Federal Building, Water and Dickson Streets. 1936. Preserve. A very good freestone building; fine interior largely intact. The building is an excellent fit with the quite rich architectural legacy of Galt.
Chesley, Ont.	Post Office, Main Street. 1911. Preserve. A romantic composition of the basic Ewart type, with a unique double portico arrangement.
Cochrane, Ont.	Public Building, Sixth Avenue, 1935. Maintain. A fairly large, scraped-Classical two-storey building in stone, somewhat like Kitchener, with much heraldic ornament hung about the façade. A mid-block site, with (in 1965) a theatre to one side and a bank to the other. Altered and added to in 1965. The original windows on the façade were removed. The drawing style of the original plans is not typical of Public Works, but the drawings are unsigned. Further research may reveal an outside architect. (Not visited.)
Collingwood, Ont.	Federal Building, 44 Hurontario Street. 1913. Important. A very active, full-blown Beaux Arts façade, and an interior decorating scheme using Caen stone and enriched elliptical vaulted ceilings. Front porches nicely repaired in 1960. The building is on a mid-block site in the centre of downtown, and seems quite small in context. But once discovered it is a compelling little gem in white marble, glowing amongst its red brick neighbours. It is remarkably well preserved, although a few jarring alterations have occurred, such as the bland 50's service counter, and the suspended strip fluorescent lighting. Philip C. Palin, of Collingwood, architect.
Deseronto, Ont.	Post Office, Main and Centre Streets. 1900. Preserve. Not visited; a fine stone building in the manner of Thomas Fuller, known to us by reputation and photographs.

Dundas, Ont.	Federal Building, 106 King Street West. 1911. Preserve. An interesting, substantial building in an important location. The area was under study as a conservation area; public interest was high.
Dunnville, Ont.	Federal Building, Broad and Chestnut Streets. 1935. Maintain. A pleasant, domed, angle corner, vaguely Deco type in brick. Sympathetic to a pleasant but newish little town.
Elora, Ont.	Post Office, 53 Geddes Street. 1910. Preserve. Very interesting stone Ewart type with tower, sympathetic to its location at the centre of a charming old mill town.
Exeter, Ont.	Old Post Office, 406 Main Street. 1929. Maintain. A pleasant, Classical variation on the small post office of its time, now recycled for town offices.
Fergus, Ont.	Federal Building, 229 St. Andrews Street West. 1910. Preserve. A fieldstone Ewart type somewhat like nearby Elora. A major architectural event in a quite pleasing town.
Forest, Ont.	Federal Building, King and Wellington Streets. 1939. Insignificant. Simple asymmetrical boxy building in an uninteresting town. Now rented to the town.
Fort Erie, Ont.	Federal Building, 55 Jarvis Street. 1936. Maintain. A scraped-Classical limestone building in a street of similarly scaled buildings in brick.
Fort Frances, Ont.	Public Building, Scott Street and Portage Avenue. 1929. Maintain. A mid-size two-storey brick Georgian/Classical building with a frontispiece in cut stone. Addition to rear, 1954. Pleasant in the drawings, but not special. Site purchased in 1912. (Not visited.)
Gore Bay, Ont.	Public Building, Meredith and Eleanor Streets. 1930. Maintain. This is a small one and one-half storey brick "cottage" type post office of the period with its gabled entrance bay in the right-hand corner of the building. It is located on a fairly generous lot purchased in 1915. The value of the building will depend entirely on its relation to the rest of Gore Bay. (Not visited.)

Gravenhurst, Ont.	Public Building, Muskoka and Bay Streets. 1926, 1934. Preserve. A good standard post office, built in two stages. (Second storey and tower added in 1934). The clock tower marks the main corner of the town, and is the focus of the business district. The second floor is occupied by offices and a residence. Social heritage value very high: an essential building in Gravenhurst. Opportunity exists to participate in present (1981/82) downtown street rehabilitation with our prominent corner and need for handicapped ramps.
Guelph, Ont.	Dominion Public Building, 138 Wyndham Street. 1935. Preserve. Moderate size, high-style Art Deco building. Has good colour and proportions, and a positive relationship with the street.
Hamilton, Ont.	Dominion Public Building, 10 John Street. 1935. Important. Our best Art Deco interior. Important to its area downtown. See Heritage Report.
Hamilton, Ont.	Postal Station 'B', 582 Barton Street. 1919. Maintain. An articulated brick solid quite suitable to its older working-class neighbourhood.
Harriston, Ont.	Post Office, Elora and Main Streets. 1911. Maintain. A typical Ewart type in a pleasant small town.
Kapuskasing, Ont.	Public Building, 22 Circle Street. 1939. Maintain. A truncated wedge on an irregular site facing The Circle, this is a simple brick building, ornamented only with pattern brick and a galvanized iron cornice. Added to with some sensitivity in 1958. Lucien LeBlanc of Ottawa, original architect. (Not visited.)
Keewatin, Ont.	Public Building, 8th and Ottawa Streets, 1930. Maintain. This is a paradigm cottage-type post office, brick, one and one-half stories, with gabled projecting central entrance bay. These small buildings are generally modestly appropriate to the small towns they are found in, but offer no spectacular presence of focus. Again, the final evaluation of this building will depend largely on its significance in Keewatin. (Not visited.)

Kingston, Ont.	Customs House, Clarence Street. 1856. Important.
Kingston, Ont.	Old Post Office, Clarence Street. 1856. Important. The two buildings and the park between form one of our most important complexes. See various Heritage Reports.
Kingston, Ont.	Caretaker's Cottage, Clarence Street. Preserve. This charming rough stone cottage is integral to the complex, and supports the two Important buildings.
Kingston, Ont.	Old Graving Dock and Pumphouse, 1889-90. Important. This site is leased to the City of Kingston for the Kingston Marine Museum. The dry-dock itself is a designated National Historic Site under the Historic Sites and Monuments Board. The attendant pumphouse contains original machinery of great technological interest.
Kingston, Ont.	St. Helen's, 440 King Street West. 1837. Important. This is a wonderful Regency villa in good grounds with some supporting buildings, all of which are included in the designation. Designated by the City of Kingston under the Ontario Heritage Act.
Kirkland Lake, Ont.	Federal Building, Kirkland and Duncan Streets. 1935. Not visited; no classification.
Kitchener, Ont.	Federal Building, 15 Duke Street. 1937. Preserve. Medium size Art Deco building of some accomplishment, with very pleasant grounds facing Market Square. Grounds are a needed relief; the building is now altered inside.
Lakefield, Ont.	Post Office, Bridge and Queen Streets. 1913. Preserve. Ewart post office with interesting tower. Supports neighbouring Town Hall.
Leamington, Ont.	Federal Building, Talbot and Mill Streets. 1908. Maintain. Classical building with several good additions. Well located at heart of town. Grounds provide space for totemic tourist tomato.
London, Ont.	Dominion Public Building, 457 Richmond Street. 1934. Important. A splendid Art Deco building, very important in London, and nearly intact. See Heritage Report.

Lucknow, Ont.	Federal Building, Campbell and Inglis Streets. 1938. Insignificant. A very minor exercise typical of period.
Mildmay, Ont.	Federal Building, Main Street. 1936. Maintain. A happy, well proportioned, cottage-like post office in a cross-roads town.
Millbrook, Ont.	Post Office, King and Union Streets. 1939. Insignificant. Small, Deco-influenced post office in a minor town.
Milverton, Ont.	Public Building, 323 Main Street. 1914. Preserve. A typical Ewart plan with engaged corner tower, as interpreted by a Stratford architect, Jas. S. Russel. Mid-block location. No alterations recorded. (Not visited.)
New Liskeard, Ont.	Public Building, Whitewood Avenue and Paget Street. 1931. Preserve. A medium sized, two-storey scraped-Classical building with rounded corner, clad in tapestry brick. Added to with some sensitivity in 1968. Corner site, with a fair slope, and an elaborate corner entrance. (Not visited.)
Newmarket, Ont.	Federal Building, 180 Main Street. 1914. Preserve. A fine variation on the Ewart type of post office, on a steep site at the centre of town. A major landmark and necessary monument.
Niagara Falls, Ont.	Federal Building, Queen and St. Clair Streets. 1929. Maintain. Scraped-Classical building of some pretension in an otherwise undistinguished downtown commercial strip.
Nipigon, Ont.	Public Building, Front and Second Streets. 1937. Maintain. A very ordinary small 'Deco' brick box, in three bays with central frontispiece. Added to in 1966. (Not visited.)
Norwich, Ont.	Federal Building, Main and John Streets. 1914. Maintain. Pleasant rectified Tuscan variation on the Ewart type post office, of which the tower survived a recent fire.

Palmerston, Ont.	Federal Building, William and Bell Streets. 1915. Maintain. A variation of the Ewart type with a quite baroque dome and lantern on the tower. Located in open lot off main commercial street.
Parry Sound, Ont.	Public Building, 70 James Street. 1931. Maintain. A three-storey brick scraped-Classical box with pedimented stone entrances. Added to across the back in 1957. It is a major presence in a rather undistinguished town, near the courthouse (quite pleasant) and the firehall.
Penetanguishene, Ont.	Post Office, Main Street. 1931. Maintain. A Georgian brick box well located at the centre of this small village, and appropriate to the character of the street. Now rented to the local francophone association.
Picton, Ont.	Public Building, Main Street. (1900), 1949. Insignificant. This imposing, ornamented building, built under David Ewart but clearly designed in the manner of Public Works under Thomas Fuller, was erected in 1900. In 1949 a substantial additon was built across the front of the building on land previously given back to the town as public space, which completely obscured the original façade. The 1949 addition is typical of Public Works in those years, a rigid, uncomfortable Classicising design with tentative Modern detailing. Due to this addition the building has lost its otherwise considerable architectural value.
Port Perry, Ont.	Public Building, Queen Street. 1912. Preserve. A typical Ewart post office in brick with engaged corner tower. Recently renovated in response to local pressure. Occupies a good site, its tower visible from the height of land at the edge of town as one approaches along the highway. It accurately guides the visitor to the centre of town. A handicapped ramp has been added.
Rainy River, Ont.	Public Building, Fourth Street. 1937. Maintain. A three-bay, one-storey brick box with simple brick piers and a very slightly projecting frontispiece, and straight parapet, virtually free of ornament. Varies from the usual pattern only in that there is a short wing projecting to one side, making an ell at the back of the building. (Not visited.)

Sault Ste. Marie, Ont.	Old Public Building, 690 Queen Street East. 1903. Preserve. Not visited; recently recycled; rated Preserve on documentary evidence. See Heritage Report.
Seaforth, Ont.	Post Office, Queen Street. 1911. Preserve. A massive, unique Ewart post office in sympathy with a fine street of Commercial Style and Second Empire buildings.
Sioux Lookout, Ont.	Public Building, Front Street. 1937. Maintain. A two-storey, brick, scraped-Classical building with pedimented central bay. Minimally ornamented stone doorways in the outer bays. A mid-block site. The second storey was extended over the full depth of the building in 1966. (Not visited.)
Stirling, Ont.	Post Office, North and Charlotte Streets. 1939. Not visited; no classification.
Stouffville, Ont.	Old Post Office, Main and Market Streets. 1926. Insignificant. Now in private use.
Sturgeon Falls, Ont.	Public Building, 193 King Street. (1930), 1969. Insignificant. The 1930 building was an uncomfortable brick Georgian Revival Building by P.J. O'Gorman, an indifferent architect of Sudbury. In 1969, a large addition was built, and the old building was radically refenestrated, stuccoed, and roofed in patent metal roofing. None of the original character of the building remains; this is still a significant site in the centre of Sturgeon Falls.
Sydenham, Ont.	Post Office, George Street. 1930. Not visited; no classification.
Tara, Ont.	Post Office, Main Street. 1938. Maintain. Curious but pleasant cottage with truncated hip roof.
Thessalon, Ont.	Dominion Public Building, 145 Main Street. 1939. Preserve. A very small two-bay brick box with entry through a quite elaborate pedimented frontispiece. Remarkably pleasant. No evidence of alterations. (Not visited.)
Thorold, Ont.	Post Office, 18 Front Street. 1935. Maintain. Art Deco influenced building of some power in context.

Thunder Bay, Ont.	Revenue Building, 201-203 North May Street. 1913. Preserve. A refined, distinctively Classical variation on the typical Customs Warehouse of the period, which makes an elegant contribution to Thunder Bay.
Thunder Bay, Ont.	Federal Building, 130 South Syndicate Avenue. 1934. Preserve. A surprisingly full-blooded late Beaux-Arts Classical building, which makes a considerable contribution to its street.
Tilbury, Ont.	Federal Building, Queen and Canal Streets. 1911. Maintain. Typical Ewart post office with addition, in a modest town.
Toronto, Ont.	City Delivery Building, 16 Bay Street. 1939. Variable classification. This is quite a good Moderne warehouse type, with interesting bas-reliefs, in a bad location in the shadow of the Gardiner Expressway. Would be 'Preserve' elsewhere. Final classification should depend on the situation at the time any change in use is contemplated.
Toronto, Ont.	Dominion Public Building, 1 Front Street. 1929. Important. An excellent exercise in Beaux Arts impressiveness. A major urban monument, tied visually to the Union Station to create a fine formal street. Currently being renovated.
Toronto, Ont.	Postal Station 'C', 1117 Queen Street West. 1902. Preserve. A simple, Classically proportioned brick mass suitable to its area. Recently recycled.
Toronto, Ont.	Postal Station 'D', Keele and Annette Streets. 1935. Maintain. A plain '30's industrial style building in a mixed area.
Toronto, Ont.	Postal Station 'G', 765 Queen Street East. 1913. Preserve. A fine Beaux-Arts pile, richly ornamented and formal, yet well-mannered towards an ordinary commercial street, now strongly ethnic. Building now rented to City of Toronto, apparently as storage space.

Toronto, Ont.	Postal Station 'K', 2384 Yonge Street. 1936. Preserve. Scraped Classical building with a fanciful entrance. The ample site provides visual relief in Yonge Street, although a fence makes it inaccessible to use. The site of Montgomery Tavern, of Rebellion fame, is commemorated on the flagpole.
Toronto, Ont.	Postal Station 'N', 2930 Lakeshore Road. 1935. Maintain. A modest exercise in Art Deco. The interior is largely intact. Stands out in a non-descript area.
Welland, Ont.	Federal Building, King and Division Streets. 1908, 1949. Preserve. Small, urban Gothic building with a large Moderne addition on an intersecting street, but not contiguous with the original structure. The original part is 'Preserve' as part of the Welland Canal frontage. The Moderne addition has a certain interest as well.
Wiarton, Ont.	Post Office, Bedford and George Streets. 1926. Preserve. A rather Georgian, rock-face stone building of considerable grace.
Windsor, Ont.	Old Sandwich Post Office, 3201 Sandwich Street West. 1905. Preserve. An early Ewart building still strongly influenced by the memory of Thomas Fuller. The subject of much local concern. See Heritage Report.
Windsor, Ont.	Dominion Public Building, 185 Ouelette Street. 1932. Preserve. An early high-style Art Deco building, with good coloured marble interiors, many original brass fittings, and a fine urban presence in a good downtown site.
Windsor, Ont.	Walkerville Post Office, 420 Devonshire Road. 1914. Preserve. A very pleasant Classicising brick building, just up the street from the distillery that gives the town its name.
Woodville, Ont.	Post Office, King Street. 1939. Insignificant. Small post office of no distinction in a town that matches.

Summary Classification of Hertage Buildings, 1982

Capital Region

There are 105 entries in this summary for the Capital Region, representing more than 105 buildings, of which 10 are Important, 59 are Preserve, 22 are Maintain, 4 are Insignificant, and 10 require further study before they can be classified.

Athens, Ont.	Post Office, Main and Elgin Streets. 1912 Preserve. A fairly typical Ewart post office, in brick, with an unusual dome capping the tower. Well liked in the community.
Barry's Bay, Ont.	Post Office, Main Street. (1938), 1962. Insignificant. The original, uninspiring, building was stuccoed over in 1962, leaving the post office the plainest of white boxes.
Cobden, Ont.	Post Office, Eganville Road and Highway 17. 1939. Not visited; no classification.
Renfrew, Ont.	Federal Building, Raglan Street. 1908. Preserve. A late modified Fuller-style building, prominently located at the head of the street. Nicely added to in 1956.
Rockland, Ont.	Post Office, Giroux and Laurier Streets. 1928. Not visited; no classification. Rented to the Town of Rockland.
Vankleek Hill, Ont.	Post Office, Main Street. 1937. Not visited; no classification.
Westport, Ont.	Post Office, Main and Spring Streets. 1935. Not visited; no classification.
Ottawa, Ont.	EMR Complex, Booth Street. c.1920-1940. A complex of many modest buildings of the Twenties and Thirties which needs to be further studied before classification.

Ottawa, Ont.	Military Stores Building, Cartier Square. 1900. Maintain. A pleasant brick building of concern in connection with the Drill Hall (DND) and the re-planning of Cartier Square.
Ottawa, Ont.	Old Normal School, Cartier Square. 1874-75, 1879. Important. This is an excellent work of architecture by a major Canadian architect. Historically interesting as the second Normal School built in Ontario. W.R. Strickland, Toronto, architect. Designated by the City of Ottawa under the Ontario Heritage Act.
Ottawa, Ont.	Central Experimental Farm, 1886 et seq. The C.E.F. as a whole is a heritage site. Historically and aesthetically it is significant; it is an important landmark and public educational/touristic event, and it will grow in importance as an "urban lung".
Ottawa, Ont.	Dominion Observatory, CEF #1. 1902. Important. Studies for a Royal Observatory date back to 1897, and construction of this building began in August, 1904. In 1907, the west wing, called the Transit House, was added. The interiors have been frequently altered since, but the exterior is largely intact. This is by far the best of the group of important public buildings built by David Ewart during the beautification of Ottawa early this century. Nationally known, thanks to the late, lamented "This is the Dominion Observatory time signal. The beginning of the long dash ...".
Ottawa, Ont.	Residence of the Dominion Astronomer, CEF #2. 1909. Preserve. A substantial, pleasant brick house, now converted to offices.
Ottawa, Ont.	Standardization Building, CEF #5. 1908. Preserve. A long, narrow building with a gambrel roof, originally used for the standardization of steel tapes. A curiously effective building, for all of its simplicity and lack of architectural pretension.

Ottawa, Ont.	Coelostat House, CEF #6. 1907. Maintain. A simple, functional annex in the internal angle of the Observatory.
Ottawa, Ont.	Geodetic Survey Building, CEF #7. 1913. Preserve. A simple three-storey, red brick building with stone trim and entrance details making faint reference to the Observatory nearby. Important mainly for its historical association with the massive and technically very advanced mapping projects of the Federal Government.
Ottawa, Ont.	Azimuth Mark Hut, CEF #8. 1913. Preserve. A small, octagonal stone pavilion, quoined and battlemented to within an inch of its life. Delightful.
Ottawa, Ont.	Photo Equatorial Building, CEF #9. 1913. Preserve. Originally the stellar camera hut, this is the azimuth hut plus a copper dome and stone lantern supported by dressed stone scrolls.
Ottawa, Ont.	Forage Crops Building, CEF #12. 1902, et seq. Maintain. This building began in 1902 as the four-room Laboratory No. 2, and grew like Topsy, with additions in 1917, 1927 and 1932. The 1932 addition brought the building into line with the brick and half-timber vocabulary established in the 1920's for the CEF's laboratories and offices.
Ottawa, Ont.	Storage Building, CEF #13. 1932. Maintain. It looks as if this building began as an addition to the "Seed Selecting and Preparation Building". By 1946 it had become the Seed House. No further evidence has yet been found.
Ottawa, Ont.	Old Threshing Barn, CEF #14. 1924. Maintain. A simple one storey frame building. No good evidence.

Ottawa, Ont.

K.W. Neatby Building, CEF #20. 1936.
Preserve.
The contract for this building, then the Records Storage Building, was let in August, 1936. The original part was a four-storey brick pile in an attenuated Collegiate Gothic, with considerable relief in the massing. An addition larger than the original building was built, evidently in 1948, although in looks a little later. It is a typical bland proto-Modern Public Works design. The building now houses laboratories and offices.

Ottawa, Ont.

Cytogenetics Building, CEF #26. 1915.
Maintain.
This simple little brick box with bracketted eaves and suggestions of half-timbering in the dormers was built in 1915 as the Apicultural Building. It is one of the plain minor buildings which contribute to the atmosphere of the farm.

Ottawa, Ont.

Mouse House, CEF #27. 1915?
Maintain.
A simple clapboard shed, originally called the Honey House, and of an age with the Apicultural Building. No further information available.

Ottawa, Ont.

Animal Genetics Building, CEF #34. 1920, 1939.
Preserve.
A two storey brick building with a characteristic truncated hip roof. Built in August, 1920, and doubled in size in 1939. A very pleasant building, good brickwork, and, especially in the side elevation, reminiscent of early 20th Century English design.

Ottawa, Ont.

Service Building, CEF #36. 1917.
Maintain.
We have drawings of this building back to 1917, but there is some indication that it existed earlier. It was then a poultry feed house and cockerell house. It is frame, with clapboard on the first storey and shingles on the half-storey. This is the other unifying aesthetic vocabulary of the Farm, and dates back to its founding.

Ottawa, Ont.

Animal Genetics Annex, CEF #37. 1917.
Preserve.
This was built as a brooder house. The CEF typical vocabulary of low eaves, shallow dormers, fanciful ventilators, and the gable-like dormers at the ends of the hipped roof is here nicely displayed in a very simple building.

Ottawa, Ont.	William Saunders Building, CEF #49. 1935. Preserve. This building in "a modern adaptation of Tudor Gothic", and the Neatby Building of a similar date suggest that the collegiate aspects of the Farm were uppermost in the minds of the designers at that time. Tudor Gothic is an appropriate style for serious buildings among a collection of "Tudor" half-timbered "cottages", of course. This building is quite pleasant, although skimpy in a typically 30's way.
Ottawa, Ont.	Main Greenhouses, CEF #50. 1915, et seq. Variable classification. The header house, heating plant, and central ranges were built in 1915, 1921, 1924, and 1931. The palm house was built in 1939. In the 50's the complex was rationalized and the number of greenhouses at least doubled. Greenhouses have been treated as semi-permanent structures, and were generally built from off-the-shelf components. The palm house, despite its fairly late date, is the most interesting and recognizable element. It is designated "Preserve" in its entirety and should be conserved and restored. Ornamental elements, such as the ogee curved vestibules and doors should be preserved, and moved, if necessary, in the further development of the complex.
Ottawa, Ont.	House, CEF #54. 1887. Preserve. This is one of four similar houses that were built for staff at the founding of the Farm. Our records are incomplete, and subsequent alterations make it difficult to determine which of the four this one is. In 1917 it was the Animal Husbandman's Residence, and in 1926 the residence of the Director of the Farm.
Ottawa, Ont.	Horticulture Building, CEF #55. pre-1917, et seq. Preserve. We have not yet determined the original date of this building, but we have drawings which by technique may go back to the 1880's. It has always been known as the Horticulture Building, and is obviously much altered.

Ottawa, Ont.	Packing Shed, CEF #56. c. 1918. Preserve. The original plans for this building are undated; the second-storey was added in 1933, but adhered carefully to the established vocabulary of the Farm. The building has a pleasant liveliness, and is among the best of its type.
Ottawa, Ont.	Dairy Technology Building, CEF #57. 1920. Maintain. Two-storey building, roughcast on frame with a clipped (Bernese) gables. Not very successful.
Ottawa, Ont.	Animal Nutrition Building, CEF #59. 1889 et seq. Preserve. This was Laboratory No. 1 in 1889, but the original little building is no longer really detectable. Additions 1912-16, 1924, 1936 and alterations since.
Ottawa, Ont.	Animal Research Building, CEF #60. 1889. Preserve. This is another of the original four houses built in 1889. The plan shows portions which are the mirror image of Residence No. 4. In 1917 it was the Dominion Cerealist's Residence. In 1926, it was the residence of the Dominion Animal Husbandman.
Ottawa, Ont.	Arboretum Greenhouse (Virology Lab), CEF #73. (1889?), 1925. Preserve. There is some evidence that this is the original greenhouse, but the earliest map we have does not cover this area of the Farm. The header house is a modest clapboard shed of some pleasure.
Ottawa, Ont.	Plant Research Building, CEF #74. 1924. Preserve. This is one of the few buildings on the Farm not much added to, and originally built to the brick and stucco half-timbered vocabulary of the Farm.
Ottawa, Ont.	Cereal Crops Building, CEF #75. pre-1917, 1926, et seq. Maintain. We have not been able to determine the original date of this building. In 1917 it was the Botanical Division, and in 1926 it was remodelled for the Bacteriological and Cereals Divisions, at which time the greenhouses were added. Aesthetically mixed; its many additions have not been as well handled as usual on the Farm.

Ottawa, Ont.	Cereal Cleaning Barn, CEF #76. 1915. Preserve. A very fine building in the wood vocabulary of the Farm. Second or third among these buildings, after the Main Barn and, maybe, the Piggery.
Ottawa, Ont.	Pottery Shed, CEF #77. c. 1915. Maintain. A curious building obviously of an age with others of the shingle/board and batten type buildings, but no drawings or other evidence have been found.
Ottawa, Ont.	Cereal Barn, CEF #82. pre-1926. Maintain. Parts of this barn may pre-date the Farm. In the 1935 alterations logs were removed, suggesting a fairly early technology.
Ottawa, Ont.	McNeely Residence, CEF #86. 1888, et seq. Preserve. This is one of the original four cottages built for lesser employees of the Farm. It most resembles "Cottage No. 1", but has been much altered, and not entirely sympathetically.
Ottawa, Ont.	Main Barn, CEF #88. 1887. Important. This is the central, identifying image of the Farm, and surely one of a very few architect-designed barns in Canada. Its original transverse arrangement of stalls was passing bizarre, but it was modernized in the sixties.
Ottawa, Ont.	Horse and Bull Barn, CEF #90. pre-1917, 1929. Preserve. The original date of this building may be in the 1890's, but this is unproved. We have a drawing for an addition in 1929 which brought the building to much its present shape.
Ottawa, Ont.	Calf Barn, CEF #90A. pre-1926. Maintain. This is one of the minor, movable sheds on the Farm. It seems to have been moved to this location in 1935, but its date of construction is quite obscure.

Ottawa, Ont.

Main Piggery, CEF #91. 1891, 1935.
Preserve.
Here is something quite delighful: a very architectural pig sty. A simply massed shed, low to the ground, with just enough picturesque relief in the oversize dormers and, of course, ventilators.

Ottawa, Ont.

Experimental Piggery, CEF #91A. No date.
Maintain.
A suitable adjunct to the main complex.

Ottawa, Ont.

Engineering Research Building, CEF #94. 1936.
Maintain.
This building follows the "rules" of the 30's aesthetic scheme for the Farm, but misses slightly through the choice of the wrong brick and stucco colour. The building initially housed a museum of agricultural implements on its upper floor.

Ottawa, Ont.

Large Animal Barn, CEF #95. 1916?
Preserve.
We have a drawing for a version of this building dated 1916. It is the only typical gambrel-roofed barn on the Farm.

Ottawa, Ont.

Carpenter Shop, CEF #98. c. 1916.
Preserve.
This building's original provenance is unclear; it was moved to this site in 1930 and set on new foundations. It is a fine composition in the board-and-batten vocabulary of its period on the Farm.

Ottawa, Ont.

Plot Building (Flax Mill), CEF #106. 1928.
Insignificant.
Two very fine wooden flax mills on this site burned in quick succession (1921 and 1925). This cinder block and stucco lump is the inevitable over-reaction.

Ottawa, Ont.

Old Flax Barn, CEF #108. 1918.
Maintain.
These small, pleasant sheds have been particularly mobile, and we have little record of them. This one still is not very firmly attached to the ground. Since this and the tobacco barns (following) are pleasant and in the right design mode for the Farm, they should be preserved where at all possible.

Ottawa, Ont.	Old Tobacco Barns, CEF #111,112,113, 1929, 1937, 1938. Maintain. These buildings are all of the same design; at present we do not know which was built when, and it does not much matter. They do not follow the graphically excellent traditional pattern of the tobacco areas of southern Ontario, but are pleasant in their own rights.
Ottawa, Ont.	Booth Barn, CEF #118. pre-1926. Preserve. This barn is shown on a 1926 map in much its present shape, before the Booth Farm was added to the CEF. It is an interesting agglomeration of different farm designs and functions connected into a farm compound, a rare approach in Canada. May well reward further research.
Ottawa, Ont.	Central Heating Plant, Cliff Street. 1929. Insignificant Well-placed, inasmuch as it is virtually invisible.
Ottawa, Ont.	Laurier House, 335 Laurier Avenue East. 1878. Important. An historic site, traditionally under the care of the Dominion Archivist.
Ottawa, Ont.	Old Molson's Bank, 14 Metcalfe Street. 1890's. Preserve. A handsome building in its own right, in a whimsical style now rare in Ottawa, which happens also to have housed Mackenzie King's first office in Ottawa and the first offices of the Labour Department.
Ottawa, Ont.	Victoria Museum, Metcalfe Street. 1905. Preserve. One of Ottawa's major landmarks, and representative of the urge to make Ottawa "The Washington of the North".
Ottawa, Ont.	Old Registry Office, 70 Nicholas Street. 1872. Important. As one of the few typical Registry Offices left in Ontario, this building has Provincial significance.

Ottawa, Ont.	Daly Building, Rideau Street. 1904, 1913. Preserve. Must be preserved for numerous reasons, outlined in a Heritage Report.
Ottawa, Ont.	Conference Centre (Old Union Station), Rideau Street. 1912. Preserve. The building is essential to Confederation Square, and is historically interesting, as well as being a handsome Beaux Art pile. Recyled.
Ottawa, Ont.	Government Guest House, 7 Rideau Gate. 1862, et seq. Preserve. A pleasant house, lately recycled.
Ottawa, Ont.	Rideau Hall, 1838 et seq. Important. Architecturally Rideau Hall impresses not, but historically, of course, it rates high. The grounds and outbuildings are to be treated with equal sensitivity.
Ottawa, Ont.	Air Museum, Rockcliffe. 1940's. Preserve. A number of technologically important hangars survive, of which at least one must be preserved.
Ottawa, Ont.	Stornaway, Rockcliffe. 1914. Preserve. A handsome house, residence of the Leader of the Opposition.
Ottawa, Ont.	Housing, 52-60 St. Andrew Street. Further study needed. Part of the Lowertown historical area.
Ottawa, Ont.	Post Office, 59 Sparks Street. 1938. Preserve. A fine Art Deco version of the style of the Langevin Block next door. Built to replace the original Ottawa Post Office, which was torn down to make Confederation Square. Some fine Deco interior elements remain, despite the rude introduction of "racing stripes". W.E. Noffke, Ottawa, architect.

Ottawa, Ont.	Hope Chambers, 61-63 Sparks Street. 1910. Preserve. This building housed Hope Booksellers from 1910 to about 1955. This is an early work by the important Ottawa architect, W.E. Noffke, in which he is coming to grips with the needs of taller buildings.
Ottawa, Ont.	O'Brien Building, 65 Sparks Street. c.1875. Maintain. A narrow, typical, commercial Italianate building, possibly the oldest building on Sparks Street.
Ottawa, Ont.	House of Norcanno Building, 69-71 Sparks Street. 1930's. Insignificant. It is unclear what might exist beneath the bland 30's stucco building we now see.
Ottawa, Ont.	Saxe Building, 75 Sparks Street. 1910's Preserve. This building is very like the Hope Building, but has heavier detailing. Typical of its period.
Ottawa, Ont.	Blackburn Building, 85 Sparks Street. 1908, 1913. Preserve. The building was built in three stages, starting as a narrow, seven-storey hotel in 1908 and becoming prestige offices in 1913. A fine cornice has been removed, and the ground floor insensitively altered.
Ottawa, Ont.	Telegraph Building, 93 Sparks Street. 1871. Preserve. John Kelly was the "architect and builder" of this fine stone building. The sculptural ornament is by William Hall Burns, who also sculpted figures on the Library of Parliament. First owner was the Montreal Telegraph Co.
Ottawa, Ont.	Birks Building, 107 Sparks Street. 1910's Maintain. We have not yet learned very much about this dull, much-altered building.
Ottawa, Ont.	Florsheim Building, 109-111 Sparks Street. 1910's. Preserve. This building has good Renaissance detailing in stone in the second floor, and more typical brick details above, suggesting that the building was added to.

Ottawa, Ont.	Fisher Building, 115 Sparks Street. No date. Preserve. A minimally ornamented, dressed limestone facade is topped by a standard pressed-tin cornice, of a sort available by catalogue from the mid - 19th Century through the 1920's. The building now has one of Ottawa's first modern shopfronts, installed c.1948.
Ottawa, Ont.	Bank of Commerce, 119 Sparks Street. 1922. Preserve. A handsome Beaux Arts "temple bank" with a gaint Corinthian peristyle. Designed by Darling and Pearson, *the* bank architects of the time.
Ottawa, Ont.	Bank of Nova Scotia, 125-133 Sparks Street. 1923-24. Preserve. Another Classical bank, a Renaissance base supporting a giant Doric order recessed in the facade. Designed by John M. Lyle, a very important Toronto architect.
Ottawa, Ont.	Bank of Montreal, 161 Sparks Street (144 Wellington Street). 1930-32. Preserve. This is a superb Scraped Classical/Deco Style bank, an excellent example of the bank style that succeeded the Classicism represented by the banks above. Barott and Blackader, Montreal, architects.
Ottawa, Ont.	Booth Building, 165 Sparks Street. Pre-1914. Maintain. A very large speculative office building, typical of its time. It was always a rather plain building, and has been stripped of virtually all of its ornament.
Ottawa, Ont.	Slater Building, 177-179 Sparks Street. 1894. Preserve. One of three adjoining, delightful Romanesque commercial buildings, highly ornamented, in good shape, and as a group, unique in Ottawa.
Ottawa, Ont.	Brouse Building, 181-183 Sparks Street. 1893. Preserve. The first, by a few years, of this group of Romanesque buildings. Slightly less ornamented than the Slater Building, but no less pleasing.

Ottawa, Ont.	Stephens Building, 185-187 Sparks Street. 1896. Preserve. The third of this group, and equally fine. In 1981 a new shop front, which purports to resemble the original, and fails, was built on the ground floor.
Ottawa, Ont.	Old Metropolitan Life Building, 189-195 Sparks Street. 1925-27. Preserve. A massive Beaux Arts pile with a sympathetic addition. Designed by D. Everett Wade of New York.
Ottawa, Ont.	Prime Minister's Residence, 24 Sussex Drive. 1868, et seq. Preserve. A much-altered building of obvious historical interest.
Ottawa, Ont.	National Research Council, 100 Sussex Drive. 1930. Preserve. A solid, late Beaux Arts building of modest charms, now a landmark on Sussex.
Ottawa, Ont.	Royal Canadian Mint, 320 Sussex Drive. 1905, et seq. Preserve. Obvious social and historical interest, and one of a handsome group dating from the first conscious beautification of Ottawa.
Ottawa, Ont.	War Museum, 330-350 Sussex Drive. 1907. Preserve. Remarkably popular, apparently, but architecturally rather dependant on the Mint.
Ottawa, Ont.	LaSalle Academy, 373 Sussex Drive. 1849, 1852, 1895, et seq. Preserve. A fine element in the "Mile of History". A pioneer recycling project.
Ottawa, Ont.	Connaught Building, Sussex Drive. 1913. Preserve. Held by David Ewart to be his finest work. We can at least agree that it is essential to the Sussex Drive processional.
Ottawa, Ont.	Langevin Block, 50 Wellington Street. 1883. Preserve. The first public building "off the Hill". A handsome exercise by Thomas Fuller. Recycled.

Ottawa, Ont.	U.S. Embassy, 100 Wellington Street. 1931. Important. A handsome building by an important architect, and home of the first foreign legation in Canada. Cass Gilbert, architect.
Ottawa, Ont.	Old Union Bank, 128 Wellington. 1888-89. Preserve. The last of the second Empire banks which once lined Wellington Street and provided a splendid fourth wall for the Parliament grounds.
Ottawa, Ont.	Victoria Building, 138-140 Wellington Street. 1920's. Maintain. This is an oddity of a building, designed by J.A. Ewart.
Ottawa, Ont.	Norlite Building, 150 Wellington Street. Maintain. Houses the Press Club and interview theatre seen by millions daily.
Ottawa, Ont.	East Block, Wellington Street. 1859 et seq. Important. The last intact member of the only architectural group in Canada to receive serious attention abroad before recent times, in addition to its other, more obvious, values.
Ottawa, Ont.	Centre Block, Wellington Street. 1916-27. Important. Seat of the Parliament of Canada.
Ottawa, Ont.	West Block, Wellington Street. 1859 et seq. Important. The interior of this building was mutilated in the 1950's. The exterior is Important.
Ottawa, Ont.	Confederation Building, Wellington Street. 1928. Preserve. A fine late Gothicizing building which supports the Hill in exemplary manner.
Ottawa, Ont.	Justice Building, Wellington Street. 1935. Preserve. Like the Confederation Building a superior example of architectural good manners.

Ottawa, Ont.	Justice Annex, Wellington Street. c.1942. Preserve. A little gem of its type, which ought to be seriously considered for preservation as a memento of the nearly-permanent Temporary Buildings.
Ottawa, Ont.	Supreme Court, Wellington Street. 1938. Preserve. An interesting compromise of Classical and Chateau Style inspirations. Ernest Cormier, architect.
Gatineau, Que.	Post Office, 89 Maple Street. 1940. Not visited; no classification.
Gatineau Park, Que.	Kingsmere. Preserve. Official residence of the Speaker of the House of Commons. Closely associated with Mackenzie King.
Rouyn, Que.	Federal Building, Perrault Street and Portage Avenue. 1935. Not visited; no classification.

ENVIRONMENT CANADA

Note: The following list includes buildings which have been recommended for historic commemoration. A more complete computer listing of buildings with federal heritage designation is available from:

Rosemarie Bray
Information Analysis
Canadian Inventory of
  Historic Building Section
Architectural History Branch
  Directorate
Ottawa, Ontario
613 - 237-1066

HSMBC POSITIVE RECOMMENDATIONS FOR ONTARIO

sorted by town and building name

PROVINCE	TOWN	BUILDING NAME	BUILDING CONSIDERED	ADDRESS	HSMBC NAME	CATALOGUE	PHOTO	GEOCODE
ONT	ADOLPHUSTOWN	ADOLPHUSTOWN TOWNSHIP HALL	(INDIVIDUALLY)		ADOLPHUSTOWN TOWNSHIP HALL			06
ONT	ALMONTE	ALMONTE POST OFFICE	(INDIVIDUALLY) 77	MILL STREET	FULLER POST OFFICES: ALMONTE			0615600050077
ONT	AMHERSTBURG	BELLE VUE/ REYNOLDS HOUSE	(INDIVIDUALLY) 525	DALHOUSIE STREET	BELLE VUE			0617100100525
ONT	AMHERSTBURG	BOIS BLANC ISLAND BLOCKHOUSE - NO 1	(IND & COLL)		BOIS BLANC LIGHTHOUSE AND BLOCKHOUSE			0600140000012
ONT	AMHERSTBURG	BOIS BLANC ISLAND BLOCKHOUSE - NO 2	(IND & COLL)		BOIS BLANC LIGHTHOUSE AND BLOCKHOUSE			0600140000013
ONT	AMHERSTBURG	BOIS BLANC ISLAND LIGHTHOUSE	(COLLECTIVELY)		BOIS BLANC LIGHTHOUSE AND BLOCK HOUSE			0600140000014
ONT	AMHERSTBURG	REYNOLDS HOUSE - SEE "BELLE VUE"						0617100100525
ONT	AURORA	HILLARY HOUSE	(INDIVIDUALLY) 72	YONGE STREET NORTH	HILLARY HOUSE		Y	0611900090072
ONT	BELLEVILLE	BELLEVILLE RAILWAY STATION (GRAND TRUNK)	(INDIVIDUALLY) 240	STATION STREET	RAILWAY STATIONS: (1) GRAND TRUNK LINE. STATION AT BELLEVILLE			0611100620240
ONT	BELLEVILLE	GLANMORE/ PHILLIPS-FAULKNER HOUSE/ HASTINGS COUNTY MUSEUM	(INDIVIDUALLY) 257	BRIDGE STREET EAST	GLANMORE (PHILLIPS FAULKNER HOUSE)			0611100630257
ONT	BELLEVILLE	HASTINGS COUNTY MUSEUM - SEE "GLANMORE"						[illegible]
ONT	BELLEVILLE	PHILLIPS-FAULKNER HOUSE - SEE "GLANMORE"						[illegible]
ONT	BRANTFORD	HER MAJESTY'S CHAPEL OF THE MOHAWKS - SEE "ST PAULS CHAPEL OF THE MOHAWKS"						[illegible]
ONT	BRANTFORD	MOHAWK CHURCH - SEE "ST PAULS CHAPEL OF THE MOHAWKS"						[illegible]
ONT	BRANTFORD	ST PAULS CHAPEL OF THE MOHAWKS/ MOHAWK CHURCH/ HER MAJESTY'S CHAPEL OF THE MOHAWKS	(INDIVIDUALLY)		HER MAJESTY'S CHAPEL OF THE MOHAWKS			[illegible]
ONT	BROCKVILLE	BROCKVILLE POST OFFICE	(INDIVIDUALLY) 12	COURT HOUSE AVENUE	FULLER POST OFFICES: BROCKVILLE		Y	[illegible]
ONT	BROCKVILLE	LEEDS AND GRENVILLE COUNTY COURT HOUSE	(INDIVIDUALLY) 12	COURT HOUSE SQUARE	COURT HOUSES: LEEDS AND GRENVILLE COUNTY COURT HOUSE			[illegible]

HSMBC POSITIVE RECOMMENDATIONS FOR ONTARIO
sorted by town and building name

PROVINCE	TOWN	BUILDING NAME	BUILDING CONSIDERED	ADDRESS	HSMBC NAME	CATALOGUE	PHOTO GEOCODE
ONT	CLAREMONT	THISTLE HA' FARM	(INDIVIDUALLY)		THISTLE HA' FARM		065072001 0245
ONT	COBOURG	COBOURG TOWN HALL - SEE "VICTORIA HALL"					06.7900120055
ONT	COBOURG	VICTORIA HALL/ COBOURG TOWN HALL	(INDIVIDUALLY) 55	KING STREET	VICTORIA HALL	Y	06.7800170057
ONT	CORNWALL	GART - SEE "INVERARDEN"					060.59007.0044
ONT	CORNWALL	INVERARDEN/ GART, ORIGINALLY	(INDIVIDUALLY)		INVERARDEN HOUSE		06058000100044
ONT	DELTA	STONE MILL, OLD	(INDIVIDUALLY)	HIGHWAY 42	STONE MILL, OLD		06.7900000233
ONT	GALT	GALT POST OFFICE	(INDIVIDUALLY) 1	WATER STREET	FULLER POST OFFICES: GALT	Y	06113002500012
ONT	GODERICH	HURON COUNTY JAIL	(INDIVIDUALLY) 181	VICTORIA STREET NORTH	HURON COUNTY GAOL	Y	06153005000181
ONT	GRAFTON	BARNUM HOUSE	(INDIVIDUALLY)	HIGHWAY 2	BARNUM HOUSE	Y	06003000000164
ONT	GUELPH	GUELPH CITY HALL	(INDIVIDUALLY) 59	CARDEN STREET	GUELPH CITY HALL	Y	06104004200059
ONT	GUELPH	MCCRAE, COL JOHN HOUSE	(INDIVIDUALLY) 100	WATER STREET	MCCRAE HOUSE		06104009400100
ONT	HAMILTON	BEACH PUMPHOUSE, OLD - SEE "HAMILTON WATERWORKS"					06102008300900
ONT	HAMILTON	DUNDURN CASTLE	(INDIVIDUALLY) 1000A	YORK STREET	DUNDURN CASTLE	Y	0610200180100OA
ONT	HAMILTON	HAMILTON WATERWORKS/ OLD BEACH PUMPHOUSE	(INDIVIDUALLY) 900	WOODWARD AVENUE	HAMILTON WATERWORKS		06102009300900
ONT	HAMILTON	MCQUESTON HOUSE/ WHITEHERN	(INDIVIDUALLY) 41	JACKSON STREET WEST	MCQUESTON HOUSE		06102002800041
ONT	HAMILTON	SANDYFORD PLACE	(INDIVIDUALLY) 35	DUKE STREET	SANDYFORD PLACE		06102010900035
ONT	HAMILTON	WHITEHERN - SEE "MCQUESTON HOUSE"					06102002800041
ONT	KINGSTON	BELLEVUE/ HOME OF SIR JOHN A MACDONALD	(INDIVIDUALLY) 35	CENTRE STREET	BELLEVUE HOUSE		06106002500035
ONT	KINGSTON	COMMANDANTS HOUSE AND WALL	(COLLECTIVELY) 1	ROYAL MILITARY COLLEGE	POINT FREDERICK BUILDINGS, ROYAL MILITARY COLLEGE		06106010800001
ONT	KINGSTON	COTTAGE	(COLLECTIVELY) 3	ROYAL MILITARY COLLEGE	POINT FREDERICK BUILDINGS, ROYAL MILITARY COLLEGE		06106010800003

HSMBC POSITIVE RECOMMENDATIONS FOR ONTARIO
sorted by town and building name

BUILDING ADDRESS HSMBC CATALOGUE PHOTO GEOCODE

ONT	KINGSTON	BELLEVUE/ HOME OF SIR JOHN A MACDONALD	(INDIVIDUALLY) 35	CENTRE STREET	BELLEVUE HOUSE		06106002500035
ONT	KINGSTON	COMMANDANTS HOUSE AND HALL	(COLLECTIVELY) 1	ROYAL MILITARY COLLEGE	POINT FREDERICK BUILDINGS, ROYAL MILITARY COLLEGE		06106010600001
ONT	KINGSTON	COTTAGE	(COLLECTIVELY) 3	ROYAL MILITARY COLLEGE	POINT FREDERICK BUILDINGS, ROYAL MILITARY COLLEGE		06106010800003

HSMBC POSITIVE RECOMMENDATIONS FOR ONTARIO
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PROVINCE	TOWN	BUILDING NAME	BUILDING CONSIDERED	ADDRESS	HSMBC NAME	CATALOGUE	PHOTO GEOCODE
ONT	KINGSTON	FRONTENAC COUNTY COURT HOUSE	(INDIVIDUALLY) 1	COURT STREET	COURT HOUSES: FRONTENAC COUNTY COURT HOUSE		Y 06106006000001
ONT	KINGSTON	GATEHOUSE	(COLLECTIVELY) 2	ROYAL MILITARY COLLEGE	POINT FREDERICK BUILDINGS, ROYAL MILITARY COLLEGE		06106010800002
ONT	KINGSTON	KINGSTON CITY HALL	(INDIVIDUALLY) 216	ONTARIO STREET	KINGSTON CITY HALL		Y 06106000600216
ONT	KINGSTON	KINGSTON CUSTOMS HOUSE, OLD	(INDIVIDUALLY) 294	KING STREET EAST	KINGSTON CUSTOM HOUSE		Y 06106000400294
ONT	KINGSTON	KINGSTON POST OFFICE BUILDING, OLD	(INDIVIDUALLY) 94	CLARENCE STREET	KINGSTON POST OFFICE		Y 06106003700094
ONT	KINGSTON	MACKENZIE BUILDING	(COLLECTIVELY) 4	ROYAL MILITARY COLLEGE	POINT FREDERICK BUILDINGS, ROYAL MILITARY COLLEGE		06106010600004
ONT	KINGSTON	MURNEY MARTELLO TOWER	(INDIVIDUALLY)		MURNEY MARTELLO TOWER		06106002900018
ONT	KINGSTON	ROSELAWN	(INDIVIDUALLY) 421	UNION STREET WEST	ROSELAWN		06106007600421
ONT	KINGSTON	STONE FRIGATE	(IND & COLL) 5	ROYAL MILITARY COLLEGE	POINT FREDERICK BUILDINGS, ROYAL MILITARY COLLEGE		06106010800005
ONT	KITCHENER	DOON SCHOOL OF FINE ARTS - SEE "WATSON, HOMER HOUSE"					06124005301754
ONT	KITCHENER	WATSON, HOMER HOUSE/ DOON SCHOOL OF FINE ARTS	(INDIVIDUALLY) 1754	OLD MILL ROAD	WATSON, HOMER HOUSE		06124005301754
ONT	KITCHENER	WOODSIDE W L MACKENZIE KING BIRTHPLACE	(INDIVIDUALLY) 528	WELLINGTON STREET NORTH	WOODSIDE		06124002600528
ONT	LONDON	A BLOCK - SEE "WOLSELEY BARRACKS"					06108999900007
ONT	LONDON	ANDERSON RESIDENCE	(COLLECTIVELY) 451	RIDOUT STREET NORTH	RIDOUT ST COMPLEX		06108002600451
ONT	LONDON	GORE BANK OF CANADA	(COLLECTIVELY) 445	RIDOUT STREET NORTH	RIDOUT ST COMPLEX		06108002600445
ONT	LONDON	INFANTRY SCHOOL BUILDING - SEE "WOLSELEY BARRACKS"					06108999900003
ONT	LONDON	MIDDLESEX COUNTY COURT HOUSE	(INDIVIDUALLY) 399	RIDOUT STREET NORTH	COURT HOUSES: MIDDLESEX COURT HOUSE		06108002600399
ONT	LONDON	UPPER CANADA, BANK OF	(COLLECTIVELY) 435	RIDOUT STREET NORTH	RIDOUT ST COMPLEX		06108002600435
ONT	LONDON	WOLSELEY BARRACKS/ "A" BLOCK/ INFANTRY SCHOOL BUILDING	(INDIVIDUALLY)		WOLSELEY BARRACKS		06108999900007

HSMBC POSITIVE RECOMMENDATIONS FOR ONTARIO
sorted by town and building name

PROVINCE	TOWN	BUILDING NAME	BUILDING CONSIDERED	ADDRESS	HSMBC NAME	CATALOGUE	PHOTO GEOCODE
ONT	MAITLAND	HOMEWOOD/ SOLOMON JONES HOUSE	(INDIVIDUALLY)		HOMEWOOD		06109200000041
ONT	MAITLAND	JONES, SOLOMON HOUSE - SEE "HOMEWOOD"					06117200000041
ONT	MERRICKVILLE	MERRICKVILLE BLOCKHOUSE	(INDIVIDUALLY) 279	SAINT LAWRENCE STREET	MERRICKVILLE BLOCKHOUSE		06182000500279
ONT	MOOSE FACTORY	MOOSE FACTORY BUILDINGS	(COLLECTIVELY)		MOOSE FACTORY BUILDINGS		060074
ONT	NAPANEE	NAPANEE TOWN HALL	(INDIVIDUALLY) 12	MARKET SQUARE	NAPANEE TOWN HALL		06163003200012
ONT	NIAGARA FALLS	ELECTRICAL DEVELOPMENT CO GENERATING STATION - SEE "TORONTO POWER GENERATING STATION"					06338999900003
ONT	NIAGARA FALLS	ELECTRICAL DEVELOPMENT CO GENERATING STATION POWER HOUSE - SEE "TORONTO POWER GENERATING POWER HS"					0633899990003A
ONT	NIAGARA FALLS	TORONTO POWER GENERATING STATION POWER HOUSE	(INDIVIDUALLY)		ELECTRICAL DEVELOPMENT CO GENERATING STATION POWER HOUSE		0633899990003A
ONT	NIAGARA FALLS	TORONTO POWER GENERATING STATION/ ELECTRICAL DEVELOPMENT CO GENERATING STATION	(INDIVIDUALLY)		ELECTRICAL DEVELOPMENT CO GENERATING STATION		06338999900003
ONT	NIAGARA ON THE LAKE	BUTLERS BARRACKS COMPLEX/ BUILDING NO 1	(COLLECTIVELY)		BUTLERS BARRACKS		06132004300003
ONT	NIAGARA ON THE LAKE	BUTLERS BARRACKS COMPLEX/ BUILDING NO 2	(IND & COLL)		BUTLERS BARRACKS		06132004300002
ONT	NIAGARA ON THE LAKE	BUTLERS BARRACKS COMPLEX/ BUILDING NO 3	(COLLECTIVELY)		BUTLERS BARRACKS		06132004300003
ONT	NIAGARA ON THE LAKE	BUTLERS BARRACKS COMPLEX/ BUILDING NO 4	(COLLECTIVELY)		BUTLERS BARRACKS		06132004300004
ONT	NIAGARA ON THE LAKE	FIELDS DRUG STORE - SEE "NIAGARA APOTHECARY"					06132001700005
ONT	NIAGARA ON THE LAKE	NIAGARA APOTHECARY/ FIELDS DRUG STORE	(INDIVIDUALLY) 5	QUEEN STREET	NIAGARA APOTHECARY		06132001700005
ONT	NIAGARA ON THE LAKE	NIAGARA DISTRICT COURT HOUSE & TOWN HALL	(INDIVIDUALLY) 26	QUEEN STREET	COURT HOUSES: NIAGARA DISTRICT COURT HOUSE	Y	06132001700026
ONT	OTTAWA	ABERDEEN PAVILION/ CATTLE CASTLE	(INDIVIDUALLY) 12	LANDSDOWNE PARK	ABERDEEN PAVILION	Y	06107016900012
ONT	OTTAWA	BELL BLOCK - SEE "CONNAUGHT RESTAURANT"					06107003000032

ONT	NIAGARA ON THE LAKE	NIAGARA DISTRICT COURT HOUSE & TOWN HALL	(INDIVIDUALLY) 26	QUEEN STREET	COURT HOUSES: NIAGARA DISTRICT COURT HOUSE		Y	06132001700026
ONT	OTTAWA	ABERDEEN PAVILION/ CATTLE CASTLE	(INDIVIDUALLY) 12	LANDSDOWNE PARK	ABERDEEN PAVILION		Y	06107016900012
ONT	OTTAWA	BELL BLOCK - SEE "CONNAUGHT RESTAURANT"						06107003000032

HSMBC POSITIVE RECOMMENDATIONS FOR ONTARIO
sorted by town and building name

PROVINCE	TOWN	BUILDING NAME	BUILDING CONSIDERED	ADDRESS	HSMBC NAME	CATALOGUE	PHOTO	BEBCODE
ONT	OTTAWA	BILLINGS, BRADDISH HOUSE/ PARK HILL	(INDIVIDUALLY) 2100	CABOT STREET	BILLINGS HOUSE		Y	06107000102100
ONT	OTTAWA	CATTLE CASTLE - SEE "ABERDEEN PAVILION"						06107016900012
ONT	OTTAWA	CENTRAL CHAMBERS	(COLLECTIVELY) 40	ELGIN STREET	CONFEDERATION SQUARE			06107003000040
ONT	OTTAWA	CENTRE BLOCK/ PARLIAMENT BUILDINGS	(COLLECTIVELY) 12	PARLIAMENT HILL	PARLIAMENT BUILDINGS			06107020500012
ONT	OTTAWA	CHATEAU LAURIER	(IND & COLL) 1	RIDEAU STREET	CHATEAU STYLE RAILWAY HOTELS: CHATEAU LAURIER/ CONFEDERATION SQUARE			06107001100001
ONT	OTTAWA	CLARENDON HOTEL - SEE "MINES BUILDING, OLD"						06107004400541
ONT	OTTAWA	CONNAUGHT RESTAURANT/ BELL BLOCK	(COLLECTIVELY) 32	ELGIN STREET	CONFEDERATION SQUARE			06107003000032
ONT	OTTAWA	DALY BUILDING	(COLLECTIVELY) 555	MACKENZIE AVENUE	CONFEDERATION SQUARE			06107017900555
ONT	OTTAWA	EAGLES CLIFF - SEE "EARNESCLIFFE"						06107004400012
ONT	OTTAWA	EARNESCLIFFE/ EAGLES CLIFF	(INDIVIDUALLY) 12	SUSSEX DRIVE	EARNSCLIFFE			06107004400012
ONT	OTTAWA	EAST BLOCK/ PARLIAMENT BUILDINGS	(COLLECTIVELY) 92	PARLIAMENT HILL	CONFEDERATION SQUARE/ PARLIAMENT BUILDINGS			06107020500092
ONT	OTTAWA	GEOLOGICAL MUSEUM - SEE "MINES BUILDING, OLD"						0610700440054.
ONT	OTTAWA	LANGEVIN BLOCK	(IND & COLL) 62	WELLINGTON STREET	CONFEDERATION SQUARE/ LANGEVIN BLOCK			061070115[illegible]62
ONT	OTTAWA	LAURIER HOUSE	(INDIVIDUALLY) 335	LAURIER AVENUE EAST	LAURIER HOUSE			06107003E00335
ONT	OTTAWA	MINES BUILDING, OLD/ CLARENDON HOTEL/ GEOLOGICAL MUSEUM	(INDIVIDUALLY) 541	SUSSEX DRIVE	MINES BUILDING, OLD			06107004400541
ONT	OTTAWA	NATIONAL ARTS CENTRE	(COLLECTIVELY) 32	ELGIN STREET	CONFEDERATION SQUARE			06107003000032
ONT	OTTAWA	OTTAWA POST OFFICE	(COLLECTIVELY) 22	ELGIN STREET	CONFEDERATION SQUARE			06107007000022
ONT	OTTAWA	OTTAWA TEACHERS COLLEGE, FORMERLY	(INDIVIDUALLY) 195	ELGIN STREET	OTTAWA TEACHERS COLLEGE		Y	06107003000195
ONT	OTTAWA	PARK HILL - SEE "BILLINGS, BRADDISH HOUSE"						06107000102100

HSMBC POSITIVE RECOMMENDATIONS FOR ONTARIO
sorted by town and building name

PROVINCE	TOWN	BUILDING NAME	BUILDING CONSIDERED	ADDRESS	HSMBC NAME	CATALOGUE	PHOTO	GEOCODE
ONT	OTTAWA	PARLIAMENT BUILDINGS - SEE "EAST BLOCK"						06107020500092
ONT	OTTAWA	PARLIAMENT BUILDINGS - SEE "PARLIAMENTARY LIBRARY"						061070205000?2
ONT	OTTAWA	PARLIAMENT BUILDINGS - SEE "WEST BLOCK"						06107020500052
ONT	OTTAWA	PARLIAMENTARY LIBRARY/ PARLIAMENT BUILDINGS	(COLLECTIVELY) 32	PARLIAMENT HILL	PARLIAMENT BUILDINGS			06107020500032
ONT	OTTAWA	RIDEAU HALL	(INDIVIDUALLY) 138	SUSSEX DRIVE	RIDEAU HALL			06107004400138
ONT	OTTAWA	ROYAL CANADIAN MINT	(INDIVIDUALLY) 320	SUSSEX DRIVE	ROYAL CANADIAN MINT		Y	06107004400320
ONT	OTTAWA	SCOTTISH - ONTARIO CHAMBERS	(COLLECTIVELY) 42	SPARKS STREET	CONFEDERATION SQUARE			06107004200042
ONT	OTTAWA	UNION STATION	(COLLECTIVELY) 2	RIDEAU STREET	CONFEDERATION SQUARE			06107001100002
ONT	OTTAWA	WEST BLOCK/ PARLIAMENT BUILDINGS	(COLLECTIVELY) 52	PARLIAMENT HILL	PARLIAMENT BUILDINGS			06107020500052
ONT	OXFORD MILLS	OXFORD ON RIDEAU TOWNSHIP HALL	(INDIVIDUALLY)		OXFORD ON RIDEAU TOWNSHIP HALL		Y	06008000000465
ONT	PERTH	CAMPBELL, ARCHIBALD HOUSE - SEE "MATHESON HOUSE"						06157000200011
ONT	PERTH	MATHESON HOUSE/ ARCHIBALD CAMPBELL HOUSE	(INDIVIDUALLY) 11	GORE STREET WEST	MATHESON HOUSE		Y	06157000200011
ONT	PERTH	MCMARTIN HOUSE	(INDIVIDUALLY) 1	HARVEY STREET	MCMARTIN HOUSE		Y	06157001500012
ONT	PERTH	PERTH TOWN HALL	(INDIVIDUALLY) 8	GORE STREET EAST	PERTH TOWN HALL		Y	06157000200080
ONT	PETERBOROUGH	PETERBOROUGH LIFT LOCK	(INDIVIDUALLY)		PETERBOROUGH LIFT LOCK			06133
ONT	PETROLIA	PETROLIA TOWN HALL - SEE "VICTORIA HALL"						06240000200411
ONT	PETROLIA	VICTORIA HALL/ PETROLIA TOWN HALL	(INDIVIDUALLY) 411	GREENFIELD STREET	VICTORIA HALL			06240000200411
ONT	POINT CLARK	POINT CLARK LIGHTHOUSE	(INDIVIDUALLY)		POINT CLARK LIGHTHOUSE			06012800000261
ONT	POINTE FORTUNE	MACDONELL HOUSE/ POPLAR HOUSE	(INDIVIDUALLY)		MACDONELL HOUSE			06000300000008
ONT	POINTE FORTUNE	POPLAR HOUSE - SEE "MACDONELL HOUSE"						06000300000008

HSMBC POSITIVE RECOMMENDATIONS FOR ONTARIO

PROVINCE	TOWN	BUILDING NAME	BUILDING CONSIDERED	ADDRESS	HSMBC NAME	CATALOGUE	PHOTO	GEOCODE
ONT	PETROLIA	VICTORIA HALL/ PETROLIA TOWN HALL	(INDIVIDUALLY) 411	GREENFIELD STREET	VICTORIA HALL			06240000200411
ONT	POINT CLARK	POINT CLARK LIGHTHOUSE	(INDIVIDUALLY)		POINT CLARK LIGHTHOUSE			06012800000261
ONT	POINTE FORTUNE	MACDONELL HOUSE/ POPLAR HOUSE	(INDIVIDUALLY)		MACDONELL HOUSE			06000300000008
ONT	POINTE FORTUNE	POPLAR HOUSE - SEE "MACDONELL HOUSE"						06000300000008

HSMBC POSITIVE RECOMMENDATIONS FOR ONTARIO
sorted by town and building name

PROVINCE	TOWN	BUILDING NAME	BUILDING CONSIDERED	ADDRESS	HSMBC NAME	CATALOGUE	PHOTO	GEOCODE
ONT	PORT PERRY	PORT PERRY TOWN HALL	(INDIVIDUALLY)		PORT PERRY TOWN HALL		Y	06455999900001
ONT	PRESCOTT	PRESCOTT RAILWAY STATION (GRAND TRUNK)	(INDIVIDUALLY) 820	ST LAWRENCE STREET	RAILWAY STATIONS: (I) GRAND TRUNK LINE. STATION AT PRESCOTT			06146001000320
ONT	ROCHES POINT	BEECHCROFT	(INDIVIDUALLY)		LAKEHURST AND BEECHCROFT, GARDENS AT			06013000000035
ONT	ROCHES POINT	LAKEHURST	(INDIVIDUALLY)		LAKEHURST AND BEECHCROFT, GARDENS AT			06013000000120
ONT	SAULT STE MARIE	ERMATINGER,CHARLES OAKES HOUSE/OLD STONE HOUSE	(INDIVIDUALLY) 831	QUEEN STREET EAST	ERMATINGER HOUSE			06204000200831
ONT	SAULT STE MARIE	STONE HOUSE, OLD - SEE "ERMATINGER, CHARLES OAKES HOUSE"						06204000200331
ONT	SIMCOE	CAMPBELL-REID HOUSE - SEE "LYNNWOOD"						06205000100021
ONT	SIMCOE	LYNNWOOD/ CAMPBELL-REID HOUSE	(INDIVIDUALLY) 21	LYNNWOOD AVENUE	LYNNWOOD (CAMPBELL - REID HOUSE)			06205000100021
ONT	SMITHS FALLS	SCHERZER ROLLING LIFT BASCULE BRIDGE (CNR)	(INDIVIDUALLY)		BASCULE BRIDGE (SCHERZER ROLLING LIFT)			06382999900001
ONT	SMITHS FALLS	SMITHS FALLS RAILWAY STATION (CANADIAN NORTHERN)	(INDIVIDUALLY) 80	ABBOT STREET	RAILWAY STATIONS: (II) CANADIAN NORTHERN RAILWAY STATION			0638200[illegible]
ONT	ST MARYS JUNCTION	ST MARYS JUNCTION RAILWAY STATION (GT)	(INDIVIDUALLY)		RAILWAY STATIONS: (I) GRAND TRUNK LINE. STATION AT ST MARYS			06017600[illegible]
ONT	ST THOMAS	ST THOMAS CITY HALL	(INDIVIDUALLY) 366	TALBOT STREET	ST THOMAS CITY HALL		Y	0620700[illegible]
ONT	STRATFORD	STRATFORD CITY HALL	(INDIVIDUALLY) 1	TOWN SQUARE	STRATFORD CITY HALL		Y	06206[illegible]
ONT	TORONTO	BROWN, GEORGE HOUSE	(INDIVIDUALLY) 186	BEVERLY STREET	BROWN ,GEORGE (HOUSE)			06101014000186
ONT	TORONTO	CANADA, OLD BANK OF - SEE 'TORONTO POST OFFICE"						0610100740009[illegible]
ONT	TORONTO	EATONS COLLEGE STREET STORE/ ROUND ROOM	(INDIVIDUALLY)	COLLEGE STREET	EATONS ROUND ROOM			0610101750[illegible]
ONT	TORONTO	EATONS COLLEGE STREET STORE/ SEVENTH FLOOR AUDITORIUM	(INDIVIDUALLY) 22	COLLEGE STREET	EATON AUDITORIUM - 7TH FLOOR			0610101350[illegible]

HSMBC POSITIVE RECOMMENDATIONS FOR ONTARIO
sorted by town and building name

PROVINCE	TOWN	BUILDING NAME	BUILDING CONSIDERED	ADDRESS	HSMBC NAME	CATALOGUE	PHOTO	RECORD
ONT	TORONTO	GRANGE, THE	(INDIVIDUALLY) 317	DUNDAS STREET WEST	GRANGE, THE		Y	06101013900317
ONT	TORONTO	MASSEY HALL	(INDIVIDUALLY) 178	VICTORIA STREET	MASSEY HALL			06101006100178
ONT	TORONTO	METALLIC ROOFING COMPANY OFFICES	(INDIVIDUALLY) 1184	KING STREET WEST	METALLIC ROOFING COMPANY OFFICES			06101001501184
ONT	TORONTO	OSGOODE HALL	(INDIVIDUALLY) 1402	QUEEN STREET EAST	OSGOODE HALL		Y	061010791001402
ONT	TORONTO	ROYAL ALEXANDRA THEATRE	(INDIVIDUALLY)		NOT ON LIST TO DATE			06101011600260
ONT	TORONTO	SEVENTH POST OFFICE - SEE "TORONTO POST OFFICE"						06101003400010
ONT	TORONTO	ST LAWRENCE HALL	(INDIVIDUALLY) 157	KING STREET EAST	ST LAWRENCE HALL			6101003900157
ONT	TORONTO	TORONTO CITY HALL & COURT HOUSE, OLD	(INDIVIDUALLY) 60	QUEEN STREET WEST	TORONTO CITY HALL AND COURT HOUSE, OLD		Y	06101012800060
ONT	TORONTO	TORONTO POST OFFICE/ OLD BANK OF CANADA BLDG/ SEVENTH POST OFFICE	(INDIVIDUALLY) 10	TORONTO STREET	TORONTO POST OFFICE/ BANK OF CANADA BUILDING,OLD		Y	06101003400010
ONT	TORONTO	UNION STATION	(INDIVIDUALLY) 65	FRONT STREET WEST	RAILWAY STATIONS: (9) UNION STATION		Y	06101013300065
ONT	TORONTO	UNIVERSITY COLLEGE	(INDIVIDUALLY) 15	KINGS COLLEGE CIRCLE	UNIVERSITY COLLEGE		Y	06101016600015
ONT	TORONTO	UPPER CANADA, BANK OF BUILDING, FORMER	(INDIVIDUALLY) 252	ADELAIDE STREET EAST	BANK OF UPPER CANADA BUILDING		Y	06101007200252
ONT	TORONTO	WINTERGARDEN THEATRE/ YONGE STREET THEATRE	(INDIVIDUALLY) 189	YONGE STREET	WINTERGARDEN THEATRE/ ELGIN THEATRE			06101004200189
ONT	TORONTO	YONGE STREET THEATRE - SEE "WINTERGARDEN THEATRE"						06101004200189
ONT	TORONTO	YORK POST OFFICE, FOURTH	(INDIVIDUALLY)		YORK POST OFFICE			06101999900005
ONT	WILLIAMSTOWN	BETHUNE-THOMPSON HOUSE/ WHITE HOUSE	(INDIVIDUALLY)		BETHUNE - THOMPSON HOUSE		Y	06006300000050
ONT	WILLIAMSTOWN	JOHNSON, SIR JOHN HOUSE/ THE MANOR	(INDIVIDUALLY)		JOHNSON HOUSE, SIR JOHN			06006800000049
ONT	WILLIAMSTOWN	MANOR, THE -SEE "JOHNSON, SIR JOHN HOUSE"						06006800000049
ONT	WILLIAMSTOWN	WHITE HOUSE - SEE "BETHUNE-THOMPSON HOUSE"						06006300000058
ONT	WINDSOR	BABY, FRANCOIS HOUSE/ HIRAM WALKER HISTORICAL MUSEUM	(INDIVIDUALLY) 254	PITT STREET WEST	BABY HOUSE, FRANCOIS, THE			06135006600254

APPENDIX F

REVISIONS TO COMPUTER CODE

F.1 FORESTRY

****

The data that appears in the computer code should be changed as outlined in the text of the report. The places the changes should made are marked in the code. The recommendation numbers refer to recommendations in Section 3 of the text, except where otherwise not

****

```
 MODEL FORT1 VERSION OF 08/04/82 12:36
100 *
105 * FOREST AND FURS R.C.
TEMPLATE MODEL
110 *
115 COLUMNS 1979-2000
120 *
130 * DATA MODULES L500-
135 * USER INTERACTION L4000-
140 * FOLIAR. SOIL. ECONOMIC MODULES L5000-
150 * FURS MODULE L9000-
500 *
505 * FOLIAR DATA SET
510 *
515 * NOTE: PHEX IN USER INTERACTION MODULE
520 *
525 *
530 * FURS DATA SET
535 *
540 * TOTAL FUR HARVEST BASE YEAR (PELTS)
542 *
545 UTHBY=0
550 *
555 * TOTAL FUR TARGET YR.2000 (PELTS)
557 *
560 UHT=0
565 *
570 * ALL SPECIES FUR VALUE ($)
572 *
575 UCOST=0
580 *
590 *
600 *
605 * SOILS DATA SET
610 *
615 * H BALANCE (MEQ/CUNIT)
620 FHPS1=-2.761*XPOWERY(10,6)
625 FHPS2=-2.41*XPOWERY(10,6)
630 FHPS3=-4.09*XPOWERY(10,6)
635 FHPS4=-3.77*XPOWERY(10,6)
640 FHPS5=-2.90*XPOWERY(10,6)
645 FHPS6=-2.68*XPOWERY(10,6)
650 FHPS7=-1.76*XPOWERY(10,6)
655 FHPS8=-1.51*XPOWERY(10,6)
660 FHPS9=-2.19*XPOWERY(10,6)
665 FHPS10=-2.45*XPOWERY(10,6)
670 *
```

****

SUBSTITUTE ANNAL ALLOWABLE CUT (CUNITS) WITH MAXIMUM ALLOWABLE DEPLEATIONS (MAD, HECTARES) DATA

These figures should be adjusted for harvestable portion. Harvestable portion parameter values should be input to data files. A default value of 1.0 should be used until data becomes available. (Recommendation 8.)

****

```
675 * ANNUAL ALLOWABLE CUT (CUNITS)
680 *
685 FAACS1=0
690 FAACS2=0
695 FAACS3=0
700 FAACS4=0
705 FAACS5=0
710 FAACS6=0
715 FAACS7=0
720 FAACS8=0
725 FAACS9=0
730 FAACS10=0
735 *
```

****

UPDATE HARVEST/CUT DATA TO CORRESPOND TO MAD MANAGEMENT UNITS. INPUT CUT DATA BY HECTARES AND CUNITS. (RECOMMENDATION 9.)

****

```
740 * ACTUAL CUT BASE YEAR 1980 (CUNITS)
745 *
750 FACBYS1=0
755 FACBYS2=0
760 FACBYS3=0
765 FACBYS4=0
770 FACBYS5=0
775 FACBYS6=0
780 FACBYS7=0
785 FACBYS8=0
790 FACBYS9=0
795 FACBYS10=0
800 *
805 * TOTAL PRODUCTIVE AREA (KM*KM)
810 *
815 FTPFA=0
820 *
825 * CATION EXCHANGE CAPACITY (MEQ/100GR)
830 *
```

****

NEW SOILS DATA

Input new data from Agriculture Canada soils map (see Section 3.5.2). Map data should be input on a Geographic Information System (Recommendation 2. Section 6 of text).

****

```
835 FCEC=0
840 *
845 * BULK DENSITY OF FOREST SOILS (GR/CU.CM.)
850 *
855 FDENS=1.4
860 *
865 * ACTIVE DEPTH OF SOIL (CM)
870 *
875 FAD=25
880 *
885 * BASE SATURATION OF SOILS (<1)
890 *
895 FBS=0
900 *
905 * HYDROGEN ION CONC.  FROM NITROGEN FIX'N.   (MG/L)
910 *
915 FHPHN=0
920 FHICN1=XPOWERY(10,-FHPHN)
965 *
970 * RAINFALL H+ (MEQ/M*M)
975 *
980 FHEX=0
1000 *
1005 * PRECIPITATION RATE (CM/YR)
1007 *
1010 PRX=0
1015 FPRXM=PRX
1020 FPRXH=FPRXM
1025 FPRXL=FPRXM
1030 *
1035 * % EXCHANGEABLE CALCIUM (%)
1040 *
1045 FPXC=0
1050 *
1055 * BASE NITROGEN LOAD (MEQ/M*M)
1060 *
1065 CNO3=0
1070 *
1075 *
1080 *
1100 * SULFATE LOADING BASE YEAR (MEQ/M*M)
1105 *
1110  SO4=0
1120 *
4000 * USER INTERACTION MODULE
4005 *
4045 *
4050 INT RATE=&DISCOUNT RATE (<1.0)&
4055 *
4065 *
4075 *
4095 FPHSFEX=&SECONDARY FACTOR EFFECTING FOLIAR % REDUCTION IN PHOTO
CAP'Y.  DUE TO PH (NEAR 1.0)&
4100 *
4105 FEXPRF=&FACTOR EFFECTING FOLIAR % LOSS IN YIELD DUE TO % RED'N
P.C.  (NEA R 1.0)&
4110 *
4115 * SULFATE + NITRATE LOADING FROM RAINFALL
```

```
4120 *
4125 FIO3=&HOW DOES ACID DEPOSITION VARY OVER TIME: 1=CONSTANT.
2=PREVIOUS+FACTO R3, 3=PREVIOUS*FACTOR3&
4130 *
4135 FACTX3=&FACTOR3 (0 IF CONSTANT, PROPORTION IF CHANGING)&
4140 FDUMS1=CSO4 , PREVIOUS + FACTX3
4145 FDUMS2=CSO4 , PREVIOUS * FACTX3
4150 CSO4EX=IF FIO3 .EQ.  1 THEN CSO4 ELSE IF FIO3 .EQ.  2 THEN FDUMS1
ELSE FDUMS2
4155 * NATURAL LOADINGS OF HYDROGEN AND NITRATES
4165 FPHEXN= 0.025119*PRX
4175 CSO4N = (FPHEXN-1.2992)/0.50342
4185 CNO3N = 1.4278*CSO4N+16.3128
4200 * TOTAL NITRATE LOADINGS
4205 *
4210 FMMY1 = (CNO3) + 1.4278*(CSO4EX-CSO4)
4225 * HYDROGEN LOADINGS FROM ANTHROPOGENIC SOURCES
4230 FPHEX = PHEX - FPHEXN + .50432 * (CSO4EX - CSO4)
4240 FHICEX=FPHEX
4300 FHICNX=&FACTOR MULT.  BY H-ION CONC.  FROM NITROGEN FIXATION (NOT
%)&
4305 FHICN=FHICN1*FHICNX
4400 *TOTAL HYDROGEN LOADINGS
4450 FHEXT=FHICEX+FPHEXN
```

************** - CHANGES TO DEPOSITION MODEL - **********************

Recommendation numbers refer to recommendations in Section I of the text.

The natural and anthropogenic separartion of deposition levels can be eliminated (Recommendation 1.)

The data file should contain monthly data for each of the four acid deposition ions (hydrogen, sulfate, nitrate and ammonium) for wet and dry deposition separately. New variables for nitrate and ammonium need to be added. (Recommendation 2.)

For foliar (above ground) effects, the four deposition variables APHEX (hydrogen ion), CSO4EX (sulfate ion), CNO3EX (nitrate ion) and CNH4EX (ammonium ion) should be calculated as the sum of wet deposition levels for active growing months (May to October). (Recommendation 3.)

For soil effects, the four deposition variables APHEXA, CSO4EXS, CNO3EXS, and CRH4EXS should be calculated as the sum of wet and dry deposition levels for all months of the year. A user-specified parameter should be introduced which prorates annual deposition; the default should be set to 65% (Recommendations 3 and 5).

A user-specific parameter should be introduced to allow above-ground hydrogen ion deposition (APHEX) to differ from soil deposition (APHEXS). The default should equate APHEX and APHEXS. (Recommendation 4.)

The user should not input deposition levels which lie outside the range 2.5 < pH < 5.5 (Recommendation 7). This recommendation does not require changes to the code.

****

```
5000 *
5005 * FOREST SOILS MODULE
5010 *
```

```
5115 FAACTOT=SUM(FAACS1 THRU FAACS10)
5120 TOTAL ANNUAL ALLOWABLE CUT IN CUNITS = FAACTOT
5130 *
5135 FPRX=TRIRAND(FPRXL.FPRXM,FPRXH)
5145 FCYFA=TRIRAND(.568,.729,.848)
5150 FNYFA=TRIRAND(.00015,.000276,.00045
5155 *
5160 FCONA=1.0
5165 FCONB=FCONA
5170 FCONC=FCONA
5175 FOCS=FCONA
5180 FPHSA=FPHEX
5185 FCOND=FCONA
5190 FCONE=FCONA
5200 *
5210 * PROPORTION OF TOTAL ANN.  ALL.  CUT TO SPECIES #
5220 *
5400 FDFS1=FAACS1/FAACTOT . PREVIOUS FDFS1PLUS1
5405 FDFS2=FAACS2/FAACTOT , PREVIOUS FDFS2PLUS1
5410 FDFS3=FAACS3/FAACTOT , PREVIOUS FDFS3PLUS1
5415 FDFS4=FAACS4/FAACTOT , PREVIOUS FDFS4PLUS1
5420 FDFS5=FAACS5/FAACTOT , PREVIOUS FDFS5PLUS1
5425 FDFS6=FAACS6/FAACTOT , PREVIOUS FDFS6PLUS1
5430 FDFS7=FAACS7/FAACTOT . PREVIOUS FDFS7PLUS1
5435 FDFS8=FAACS8/FAACTOT , PREVIOUS FDFS8PLUS1
5440 FDFS9=FAACS9/FAACTOT , PREVIOUS FDFS9PLUS1
5445 FDFS10=FAACS10/FAACTOT , PREVIOUS FDFS10PLUS1
5525 FMULT1=(FAACS1/FAACTOT)*FHPS1,PREVIOUS FDFS1*FHPS1
5530 FMULT2=(FAACS2/FAACTOT)*FHPS2.PREVIOUS FDFS2*FHPS2
5535 FMULT3=(FAACS3/FAACTOT)*FHPS3.PREVIOUS FDFS3*FHPS3
5540 FMULT4=(FAACS4/FAACTOT)*FHPS4.PREVIOUS FDFS4*FHPS4
5545 FMULT5=(FAACS5/FAACTOT)*FHPS5.PREVIOUS FDFS5*FHPS5
5550 FMULT6=(FAACS6/FAACTOT)*FHPS6,PREVIOUS FDFS6*FHPS6
5555 FMULT7=(FAACS7/FAACTOT)*FHPS7,PREVIOUS FDFS7*FHPS7
5560 FMULT8=(FAACS8/FAACTOT)*FHPS8.PREVIOUS FDFS8*FHPS8
5565 FMULT9=(FAACS9/FAACTOT)*FHPS9,PREVIOUS FDFS9*FHPS9
5570 FMULT10=(FAACS10/FAACTOT)*FHPS10.PREVIOUS FDFS10*FHPS10
5580 FPSUM=SUM(FMULT1 THRU FMULT10)
5600 FBSX=FBS.PREVIOUS FBSPLUS1


**** - REPLACE FOLLOWING LINES 5605 TO 5698 WITH NEW SOILS MODEL - *


5605 FFX=((FCONA*FPHSA)/(FCONB*FOCS))*FPHEX+FCONC
5610 FALF=IF FBSX .LE.
0 THEN FFX ELSE 0
5615 FN01=FTPFA*FCEC*FDENS*FAD*FBSX*XPOWERY(10.8)
5620 FN02=FHICN*FTPFA*FAD*XPOWERY(10,7)
5625 FN03=FHICEX* FTPFA*XPOWERY(10.6)
5630 FD01=FTPFA*FCEC*FDENS*FAD*XPOWERY(10,8)
5635 FBSPLUS1=(FN01-(FN02+FN03+FPSUM))/FD01
5640 FCXC=FBSX*FCEC*FDENS*FPXC/100
5650 FCXCPLUS1=FBSPLUS1*FCEC*FDENS*FPXC/100
5660 FDYCPLUS1=FCYFA*(FCXCPLUS1-FCXC)
5680 FDYNX=FNYFA*FMMX1
5685 FDYN=IF FDYNX .GE.  .1908 THEN .1908 ELSE FDYNX
5687 FDYN=IF FDYNX .LT.  -.1908 THEN -.1908 ELSE FDYNX
5690 FYN=FDYN
```

```
5695 FDYA=FCOND*FALF+FCONE
5696 FDYNZ = FNYFA * CNO3N
5697 FYNZ = IF FDYNZ .GE.  .1908 THEN .1908 ELSE FDYNZ
5698 FYNZ = IF FDYNZ .LT.  -.1908 THEN -.1908 ELSE FDYNZ
```

```
*****************************************************
```

NEW SOILS MODEL:

The base saturation part is almost the same.

```
FNO1=FTPFA*FCEC*FAD*XPOWERY(10,8)
FNO3=FPHEXS*FTPFA*XPOWERY(10,6)
FDO1=FTPFA*FCEC*FDENS*FAD*XPOWERY(10,6)
FBSPLUS1=(FNO1-FNO3-FPSUM)/FDO1
```

Note no term FNO2. This is the nitrogen fixation term which has been dropped. (Recommendation 3.)
Take the change in potential yield a direct function of base saturation (Recommendation 4.):

```
FDY=FBSX/FBS - 1
```

Modify the relationship between nitrogen fertilization and change in current annual increment (Recommendation 5).

```
FDYN = .0011 * (CNO3EXS + CNH4EXS)
FDYN = IF FDYN > .046 THEN .046 ELSE FDYN
```

Set the aluminum part to zero as appropriate parameters are not currently available. (Recommendation 6.)

```
FDYA = 0
```

Total:

```
FDN = FDY + FDYN + FDYA
```

```
*************************************************************
```

```
5700 *
5705 * FOREST FOLIAR MODULE
5710 *
R5712 FPHEX1=-LOG10((FPHEX/(PRX/100))*XPOWERY(10,-6))
```

```
*************************************************************
```

As a default, make all species the same tolerance: Make line 5820 and 5870 the same as line 5755. (Recommendtion 1).

Note: The intercept of the foliar dose - response relationship shou set to 7.5. (Recommendation 2.) This change is made in the data files.

```
*************************************************************
```

```
5715 *
5720 * 1.  TOLERANT SPECIES
5725 *
5750 FUP11=UNIRAND(1.6.2.1)
```

```
5755 FUR12=UNIRAND(3.0*FPHSFEX.4.0*FPHSFEX)
5760 FPRPP1=IF FPHEX1 .LT.  FUR11 THEN 100 ELSE IF FPHEX1 .LT.  FUR12
THEN INTERPO LATION ON (FPHEX1,FUR11,100,FUR12,0) ELSE 0
5800 *
5805 * 2.  INTERMEDIATE SPECIES
5810 *
5815 FUR21=UNIRAND(1.6.2.3)
5820 FUR22=UNIRAND(3.8*FPHSFEX.4.5*FPHSFEX)
5825 FPRPP2=IF FPHEX1 .LT.  FUR21 THEN 100 ELSE IF FPHEX1 .LT.  FUR22
THEN INTERPO LATION ON (FPHEX1,FUR21,100,FUR22,0) ELSE 0
5850 *
5855 * 3.  SENSITIVE SPECIES
5860 *
5865 FUR31=UNIRAND(1.8.2.5)
5870 FUR32=UNIRAND(4.1*FPHSFEX.4.7*FPHSFEX)
5875 FPRPP3=IF FPHEX1 .LT.  FUR31 THEN 100 ELSE IF FPHEX1 .LT.  FUR32
THEN INTERPO LATION ON (FPHEX1,FUR31,100,FUR32,0) ELSE 0
5880 *
5885 *
5890 *
5900 FTR1 = TRIRAND(47*FEXPRF,51*FEXPRF,55*FEXPRF)
5910 FPLY1=INTERPOLATION ON(FPRPP1,0,0,75,FTR1,100,100)
5915 FPLY2=INTERPOLATION ON(FPRPP2.0.0,75,FTR1,100,100)
5920 FPLY3=INTERPOLATION ON(FPRPP3,0,0,75,FTR1,100,100)
5995 *
6000 *
6005 * NEW YIELD IN TIME T=T+1 ALL SPECIES (CUNITS)
6010 *
6015 FAACS1C1=FAACS1 . FAC1S1*((FYN-FPLY1/100)+1)
6020 FAACS2C1=FAACS2 . FAC1S2*((FYN-FPLY1/100)+1)
6025 FAACS3C1=FAACS3 . FAC1S3*((FYN-FPLY2/100)+1)
6030 FAACS4C1=FAACS4 , FAC1S4*((FYN-FPLY3/100)+1)
6035 FAACS5C1=FAACS5 . FAC1S5*((FYN-FPLY1/100)+1)
6040 FAACS6C1=FAACS6 , FAC1S6*((FYN-FPLY2/100)+1)
6045 FAACS7C1=FAACS7 . FAC1S7*((FYN-FPLY3/100)+1)
6050 FAACS8C1=FAACS8 . FAC1S8*((FYN-FPLY3/100)+1)
6055 FAACS9C1=FAACS9 . FAC1S9*((FYN-FPLY1/100)+1)
6060 FAACS10C1=FAACS10 , FAC1S10*((FYN-FPLY2/100)+1)
6065 FAACSTOT=SUM(FAACS1C1 THRU FAACS10C1)
6070 TOTAL FOREST YIELD IN CUNITS= FAACSTOT
6075*
6100 FDFS1PLUS1=FAACS1C1/FAACSTOT
6105 FDFS2PLUS1=FAACS2C1/FAACSTOT
6110 FDFS3PLUS1=FAACS3C1/FAACSTOT
6115 FDFS4PLUS1=FAACS4C1/FAACSTOT
6120 FDFS5PLUS1=FAACS5C1/FAACSTOT
6125 FDFS6PLUS1=FAACS6C1/FAACSTOT
6130 FDFS7PLUS1=FAACS7C1/FAACSTOT
6135 FDFS8PLUS1=FAACS8C1/FAACSTOT
6140 FDFS9PLUS1=FAACS9C1/FAACSTOT
6145 FDFS10PLUS1=FAACS10C1/FAACSTOT
6150 *
```

****************** - REMOVE THE FOLLOWING - ***********************

Remove lines 6155 - 6245 to eliminate the separation of natural and anthropogenic effects (Recommendation 1, Section 2 of the text).

```
6155 *
6158 * SUSTAINABLE YIELD WITHOUT NITROGEN AND FOLIAR EFFECTS FROM
NATURAL SOURCE S
6160 FAACS1NF=FAACS1/(FYNZ+1)
6165 FAACS2NF=FAACS2/(FYNZ+1)
6170 FAACS3NF=FAACS3/(FYNZ+1)
6172 FAACS4NF=FAACS4/(FYNZ+1)
6175 FAACS5NF=FAACS5/(FYNZ+1)
6180 FAACS6NF=FAAC36/(FYNZ+1)
6185 FAACS7NF=FAACS7/(FYNZ+1)
6186 FAACS8NF=FAACS8/(FYNZ+1)
6190 FAACS9NF=FAACS9/(FYNZ+1)
6195 FAACS10NF=FAACS10/(FYNZ+1)
6196 * SUSTAINABLE YIELD WITHOUT NITROGEN AND FOLIAR EFFECTS FROM
NATURAL SOURCE S
6197 * BUT WITH SOIL EFFECTS FROM ANTHROP^OGENIC HYDROGEN
6200 FAC1S1=FAACS1NF ,(FDYCPLUS1*FDFS1+1) * PREVIOUS FAC1S1
6205 FAC1S2=FAACS2NF .(FDYCPLUS1*FDFS2+1) * PREVIOUS FAC1S2
6210 FAC1S3=FAACS3NF ,(FDYCPLUS1*FDFS3+1) * PREVIOUS FAC1S3
6215 FAC1S4=FAACS4NF,(FDYCPLUS1*FDFS4+1)* PREVIOUS FAC1S4
6220 FAC1S5=FAACS5NF .(FDYCPLUS1*FDFS5+1) * PREVIOUS FAC1S5
6225 FAC1S6=FAACS6NF .(FDYCPLUS1*FDFS6+1) * PREVIOUS FAC1S6
6230 FAC1S7=FAACS7NF ,(FDYCPLUS1*FDFS7+1) * PREVIOUS FAC1S7
6235 FAC1S8=FAACS8NF ,(FDYCPLUS1*FDFS8+1) * PREVIOUS FAC1S8
6240 FAC1S9=FAACS9NF ,(FDYCPLUS1*FDFS9+1) * PREVIOUS FAC1S9
6245 FAC1S10=FAACS10NF ,(FDYCPLUS1*FDFS10+1) * PREVIOUS FAC1S10
```

To account for all impacts not just anthropogenic, add to the code:

```
FAC1S1 = FAACS1 . PREVIOUS FAC1S1C1
```

for all species

```
****************************************************************

7000 *
7005 *
7010 * ECONOMIC MODULE
7015 *

****************************************************************
```

REVISE GROWTH RATE

The growth rate PRG in line 7020 should be revised using output fr the CANDIDE or RIM models so that production forecasts across sectors are based on a common set of macroeconomic assumptions (Recommendation 13).

```
****************************************************************

7020 FGR=.0956
7025 FTIMEX=1.PREVIOUS+1

****************************************************************
```

The change in cut from one year to the next for all species should be changed as follows (Recommendation 8.):

Actual cut = minimum { Actual cut last year * growth factor;
(adjusted) MAD}

Where Maximum Allowable Depletion (MAD) is adjusted for the portion of MAD which is allocated to harvest in each management u When data become available, a harvest factor for each management unit should be input to the data files. Until that time, a default value 1.0 should be used (of line 670+) (Recommendation 8 and Section 3.5.2

****

```
7030 *
7035 * SPECIES 1
7040 *
7045 *
7050 FXS1=INTERPOLATION ON(FTIMEX,1,FACBYS1,10,FAACS1)
7055 FYS1=FXS1 FOR 10,FAACS1
7060 FZS1=FACBYS1+2*(FNS1-FACBYS1)-FACBYS1*FTIMEX*FGR
7065 FNS1=FGR*FACBYS1*10+FAACS1
7070 FEQN2S1=FACBYS1+FACBYS1*FTIMEX
7075 FAY1S1=IF FACBYS1 .LT.  FAACS1 THEN FEQN2S1 ELSE FYS1
7080 FAY2S1=IF FAY1S1 .LE.  FNS1 THEN FAY1S1 ELSE FZS1
7085 FAYS1=IF FACBYS1 .EQ.  0 THEN 0 ELSE IF FAY2S1 .LE.  FAACS1 .AND
FTIMEX .GE.  20 THEN FAACS1 ELSE FAY2S1
7095 * SPECIES 2
7100 FXS2=INTERPOLATION ON(FTIMEX,1,FACBYS2,10,FAACS2)
7105 FYS2=FXS2 FOR 10,FAACS2
7110 FZS2=FACBYS2+2*(FNS2-FACBYS2)-FACBYS2*FTIMEX*FGR
7115 FNS2=FGR*FACBYS2*10+FAACS2
7120 FEQN2S2=FACBYS2+FACBYS2*FTIMEX
7125 FAY1S2=IF FACBYS2 .LT.  FAACS2 THEN FEQN2S2 ELSE FYS2
7130 FAY2S2=IF FAY1S2 .LE.  FNS2 THEN FAY1S2 ELSE FZS2
7135 FAYS2=IF FACBYS2 .EQ.  0 THEN 0 ELSE IF FAY2S2 .LE.  FAACS2 .AND
FTIMEX .GE.  20 THEN FAACS2 ELSE FAY2S2
7145 * SPECIES 3
7150 FXS3=INTERPOLATION ON(FTIMEX,1,FACBYS3,10,FAACS3)
7155 FYS3=FXS3 FOR 10,FAACS3
7160 FZS3=FACBYS3+2*(FNS3-FACBYS3)-FACBYS3*FTIMEX*FGR
7165 FNS3=FGR*FACBYS3*10+FAACS3
7170 FEQN2S3=FACBYS3+FACBYS3*FTIMEX
7175 FAY1S3=IF FACBYS3 .LT.  FAACS3 THEN FEQN2S3 ELSE FYS3
7180 FAY2S3=IF FAY1S3 .LE.  FNS3 THEN FAY1S3 ELSE FZS3
7185 FAYS3=IF FACBYS3 .EQ.  0 THEN 0 ELSE IF FAY2S3 .LE.  FAACS3 .AND
FTIMEX .GE.  20 THEN FAACS3 ELSE FAY2S3
7195 * SPECIES 4
7200 FXS4=INTERPOLATION ON(FTIMEX,1,FACBYS4,10,FAACS4)
7205 FYS4=FXS4 FOR 10,FAACS4
7210 FZS4=FACBYS4+2*(FNS4-FACBYS4)-FACBYS4*FTIMEX*FGR
7215 FNS4=FGR*FACBYS4*10+FAACS4
7220 FEQN2S4=FACBYS4+FACBYS4*FTIMEX
7225 FAY1S4=IF FACBYS4 .LT.  FAACS4 THEN FEQN2S4 ELSE FYS4
7230 FAY2S4=IF FAY1S4 .LE.  FNS4 THEN FAY1S4 ELSE FZS4
7235 FAYS4=IF FACBYS4 .EQ.  0 THEN 0 ELSE IF FAY2S4 .LE.  FAACS4 .AND
FTIMEX .GE.  20 THEN FAACS4 ELSE FAY2S4
7245 * SPECIES 5
7250 FXS5=INTERPOLATION ON(FTIMEX,1,FACBYS5,10,FAACS5)
7255 FYS5=FXS5 FOR 10,FAACS5
```

```
7260 FZS5=FACBYS5+2*(FNS5-FACBYS5)-FACBYS5*FTIMEX*FGR
7265 FNS5=FGR*FACBYS5*10+FAACS5
7270 FEQN2S5=FACBYS5+FACBYS5*FTIMEX
7275 FAY1S5=IF FACBYS5 .LT.  FAACS5 THEN FEQN2S5 ELSE FYS5
7280 FAY2S5=IF FAY1S5 .LE.  FNS5 THEN FAY1S5 ELSE FZS5
7285 FAYS5=IF FACBYS5 .EQ.  0 THEN 0 ELSE IF FAY2S5 .LE.  FAACS5 .AND.
FTIMEX .GE.  20 THEN FAACS5 ELSE FAY2S5
7295 * SPECIES 6
7300 FXS6=INTERPOLATION ON(FTIMEX.1,FACBYS6,10,FAACS6)
7305 FYS6=FXS6 FOR 10,FAACS6
7310 FZS6=FACBYS6+2*(FNS6-FACBYS6)-FACBYS6*FTIMEX*FGR
7315 FNS6=FGR*FACBYS6*10+FAACS6
7320 FEQN2S6=FACBYS6+FACBYS6*FTIMEX
7325 FAY1S6=IF FACBYS6 .LT.  FAACS6 THEN FEQN2S6 ELSE FYS6
7330 FAY2S6=IF FAY1S6 .LE.  FNS6 THEN FAY1S6 ELSE FZS6
7335 FAYS6=IF FACBYS6 .EQ.  0 THEN 0 ELSE IF FAY2S6 .LE.  FAACS6 .AND.
FTIMEX .GE.  20 THEN FAACS6 ELSE FAY2S6
7345 * SPECIES 7
7350 FXS7=INTERPOLATION ON(FTIMEX.1,FACBYS7,10,FAACS7)
7355 FYS7=FXS7 FOR 10,FAACS7
7360 FZS7=FACBYS7+2*(FNS7-FACBYS7)-FACBYS7*FTIMEX*FGR
7365 FNS7=FGR*FACBYS7*10+FAACS7
7370 FEQN2S7=FACBYS7+FACBYS7*FTIMEX
7375 FAY1S7=IF FACBYS7 .LT.  FAACS7 THEN FEQN2S7 ELSE FYS7
7380 FAY2S7=IF FAY1S7 .LE.  FNS7 THEN FAY1S7 ELSE FZS7
7385 FAYS7=IF FACBYS7 .EQ.  0 THEN 0 ELSE IF FAY2S7 .LE.  FAACS7 .AND.
FTIMEX .GE.  20 THEN FAACS7 ELSE FAY2S7
7395 * SPECIES 8
7400 FXS8=INTERPOLATION ON(FTIMEX.1,FACBYS8.10,FAACS8)
7405 FYS8=FXS8 FOR 10,FAACS8
7410 FZS8=FACBYS8+2*(FNS8-FACBYS8)-FACBYS8*FTIMEX*FGR
7415 FNS8=FGR*FACBYS8*10+FAACS8
7420 FEQN2S8=FACBYS8+FACBYS8*FTIMEX
7425 FAY1S8=IF FACBYS8 .LT.  FAACS8 THEN FEQN2S8 ELSE FYS8
7430 FAY2S8=IF FAY1S8 .LE.  FNS8 THEN FAY1S8 ELSE FZS8
7435 FAYS8=IF FACBYS8 .EQ.  0 THEN 0 ELSE IF FAY2S8 .LE.  FAACS8 .AND.
FTIMEX .GE.  20 THEN FAACS8 ELSE FAY2S8
7445 * SPECIES 9
7450 FXS9=INTERPOLATION ON(FTIMEX.1,FACBYS9,10,FAACS9)
7455 FYS9=FXS9 FOR 10,FAACS9
7460 FZS9=FACBYS9+2*(FNS9-FACBYS9)-FACBYS9*FTIMEX*FGR
7465 FNS9=FGR*FACBYS9*10+FAACS9
7470 FEQN2S9=FACBYS9+FACBYS9*FTIMEX
7475 FAY1S9=IF FACBYS9 .LT.  FAACS9 THEN FEQN2S9 ELSE FYS9
7480 FAY2S9=IF FAY1S9 .LE.  FNS9 THEN FAY1S9 ELSE FZS9
7485 FAYS9=IF FACBYS9 .EQ.  0 THEN 0 ELSE IF FAY2S9 .LE.  FAACS9 .AND.
FTIMEX .GE.  20 THEN FAACS9 ELSE FAY2S9
7495 * SPECIES 10
7500 FXS10=INTERPOLATION ON(FTIMEX.1.FACBYS10.10.FAACS10)
7505 FYS10=FXS10 FOR 10. FAACS10
7510 FZS10=FACBYS10+2*(FNS10-FACBYS10)-FACBYS10*FTIMEX*FGR
7515 FNS10=FGR*FACBYS10*10+FAACS10
7520 FEQN2S10=FACBYS10+FACBYS10*FTIMEX
7525 FAY1S10=IF FACBYS10 .LT.  FAACS10 THEN FEQN2S10 ELSE FYS10
7530 FAY2S10=IF FAY1S10 .LE.  FNS10 THEN FAY1S10 ELSE FZS10
7535 FAYS10=IF FACBYS10 .EQ.  0 THEN 0 ELSE IF FAY2S10 .LE.  FAACS10
.AND.  FTIMEX .GE.  20 THEN FAACS10 ELSE FAY2S10
8000 *
8005 * COST CALCULATION
```

```
8010 *
8015 *

*********************************************************************
```

UPDATE COST DATA

Changes in cost should be related to cahnges in potential yield (Recommendation 10). A relationship between potential yield and delivered wood costs should be developed form new research (Recommendation 11). Until this relationship has been developed, update estimates of the most current information (Recommendation 12). Using the old relationship between tree size and costs and updated cost data, the cost of coefficient in line 8017 should be changed to:

FC = 57.89

```
*********************************************************************

8017 FC=54.33
8020 FCOSTS1=FAYS1*(1-(FAACS1C1/FAACS1))*FC
8025 FCOSTS2=FAYS2*(1-(FAACS2C1/FAACS2))*FC
8030 FCOSTS3=FAYS3*(1-(FAACS3C1/FAACS3))*FC
8035 FCOSTS4=FAYS4*(1-(FAACS4C1/FAACS4))*FC
8040 FCOSTS5=FAYS5*(1-(FAACS5C1/FAACS5))*FC
8045 FCOSTS6=FAYS6*(1-(FAACS6C1/FAACS6))*FC
8050 FCOSTS7=FAYS7*(1-(FAACS7C1/FAACS7))*FC
8055 FCOSTS8=FAYS8*(1-(FAACS8C1/FAACS8))*FC
8060 FCOSTS9=FAYS9*(1-(FAACS9C1/FAACS9))*FC
8065 FCOSTS10=FAYS10*(1-(FAACS10C1/FAACS10))*FC
8075 FCOSTSUM=SUM(FCOSTS1 THRU FCOSTS10)
8100 *
8105 * NPV CALCULATION
8110 *
8115 FNPVS1=NPVC(FCOSTS1,INT RATE,0)
8120 FNPVS2=NPVC(FCOSTS2,INT RATE,0)
8125 FNPVS3=NPVC(FCOSTS3,INT RATE,0)
8130 FNPVS4=NPVC(FCOSTS4,INT RATE,0)
8135 FNPVS5=NPVC(FCOSTS5,INT RATE,0)
8140 FNPVS6=NPVC(FCOSTS6,INT RATE,0)
8145 FNPVS7=NPVC(FCOSTS7,INT RATE,0)
8150 FNPVS8=NPVC(FCOSTS8,INT RATE,0)
8155 FNPVS9=NPVC(FCOSTS9.INT RATE,0)
8160 FNPVS10=NPVC(FCOSTS10,INT RATE,0)
8170 FNPVSUM=SUM(FNPVS1 THRU FNPVS10)
8180 FORESTS NET PRESENT VALUE = FNPVSUM - MATRIX(FNPVSUM,3)
8200 *
8205 * NTV CALCULATION
8210 *
8215 FNTVS1=NTV(FCOSTS1,INT RATE,0)
8220 FNTVS2=NTV(FCOSTS2,INT RATE,0)
8225 FNTVS3=NTV(FCOSTS3.INT RATE.0)
8230 FNTVS4=NTV(FCOSTS4,INT RATE,0)
8235 FNTVS5=NTV(FCOSTS5,INT RATE,0)
8240 FNTVS6=NTV(FCOSTS6,INT RATE,0)
8245 FNTVS7=NTV(FCOSTS7,INT RATE,0)
8250 FNTVS8=NTV(FCOSTS8,INT RATE,0)
8255 FNTVS9=NTV(FCOSTS9.INT RATE,0)
8260 FNTVS10=NTV(FCOSTS10.INT RATE.0)
8270 FNTVSUM=SUM(FNTVS1 THRU FNTVS10)
```

```
8280 NET TERMINAL VALUE = FNTVSUM - MATRIX(FNTVSUM,3)
9000 *
9005 *
9010 * FURS MODULE
9015 *
9020 *
9025 UXVAR=(FAACSTOT-FAACTOT)/FAACTOT
9035 UU1=TRIRAND(.8,1,1.2)
9040 UU2=.9*UU1
9050 UDY=INTERPOLATION ON (UXVAR, -1,-1,-.8*UU1,-.5,-.5*UU2,-
.2,0,0,.5*UU2,.2,.8* UU1,.5,1,1)
9060 USL=(UHT-UTHBY)/20
9063 UTH=UTHBY, PREVIOUS + USL
9064 TOTAL FUR HARVEST IN PELTS= UTH
9065 ULOSS=-UTH*UDY
9066 LOSS IN TOTAL FUR HARVEST IN PELTS= ULOSS
9080 UTCOST=-(UCOST/UTHBY)*UTH*UDY
9090 FURS NET PRESENT VALUE = UNPV
9095 *
9100 UNPV=NPVC(UTCOST,INT RATE,0)
9110 FURSNPV = UNPV -MATRIX(UNPV,3)
9200 UNTV=NTV(UTCOST,INT RATE,0)
END OF MODEL
```

F.2 AGRICULTURE

```
*****************************************************************
```

The data that appears in the computer code should be changed as outlined in the text of the report. The places the changes should be made are marked in the code. Recommendation numbers refer to recommendations in Section 4 of the text, except where otherwise noted.

```
********** - ADD MAPLE SUGAR AS ANOTHER CROP TYPE ******************
```

Throughout the model a 37'th crop type (Maple sugar) should be added and included in the summations. (Recommendtion 3).

```
*****************************************************************

                MODEL AGRT1  VERSION OF  08/11/82  15:02
100 *
105 * AGRICULTUAL R.C. TEMPLATE MODEL
110 *
115 COLUMNS 1979-2000
120 *
125 *
130 * DATA MODULES L500-
135 * USER INTERACTION L4000-
140 * FOLIAR,SOILS.ECONOMIC MODULES L5000-
500 *
505 * FOLIAR DATA SET
510 *
512  * RAINFALL H+ (MEQ/M*M)
515 PHE1=0
520 *

*****************************************************************

    UPDATE YIELD/CROP PRODUCTION DATA (SECTION 4.5)

*****************************************************************

    ADD MAPLE SUGAR PRODUCTION DATA FOR BASE YEAR (Recommendation 3 and
    Section 4.5)

*****************************************************************

600 * AGRICULTURAL YIELD
602 *
605 ATPAS1=0
610 ATPAS2=0
615 ATPAS3=0
620 ATPAS4=0
625 ATPAS5=0
630 ATPAS6=0
635 ATPAS7=0
640 ATPAS8=0
645 ATPAS9=0
650 ATPAS10=0
655 ATPAS11=0
660 ATPAS12=0
665 ATPAS13=0
```

```
670 ATPAS14=0
675 ATPAS15=0
680 ATPAS16=0
685 ATPAS17=0
690 ATPAS18=0
695 ATPAS19=0
700 ATPAS20=0
705 ATPAS21=0
710 ATPAS22=0
715 ATPAS23=0
720 ATPAS24=0
725 ATPAS25=0
726 ATPAS26=0
727 ATPAS27=0
728 ATPAS28=0
729 ATPAS29=0
730 ATPAS30=0
735 ATPAS31=0
740 ATPAS32=0
745 ATPAS33=0
750 ATPAS34=0
755 ATPAS35=0
760 ATPAS36=0
850 *
855 * PRECIP. RATE (CM)
860 *
865 PRX=0
866 APRXM=PRX
867 APRXH=APRXM
868 APRXL=APRXM
869 *
870 *
880 *
890 *
895 *
900 * NITROGEN LOADING BASE YEAR (MEQ/M*M)
905 *
910 CNO3=0
915 *
920 *
925 * SULFATE LOADING   BASE YEAR (MEQ/M*M)
930 *
935 CSO4=0
940 *
945 *
950 * INTEREST RATE
955 INT RATE=&INTEREST RATE (<1.0)&
960 *
4000 *
4005 * USER INTERACTION MODULE
4010 *
4015 *
4110 *
4115 * SULFATE + NITRATE LOADING FROM RAINFALL
4120 *
```

```
****************** - DEPOSITION COMPONENT  - ************************

4125 FIQ3=&HOW DOES ACID DEPOSITION VARY OVER TIME: 1=CONSTANT,
 2=PREVIOUS+FACTO R3, 3=PREVIOUS*FACTOR3&
4130 *
4135 FACTX3=&FACTOR3 (0 IF CONSTANT)&
4140 FDUMS1=CSO4 , PREVIOUS + FACTX3
4145 FDUMS2=CSO4 , PREVIOUS * FACTX3
4150 CSO4EX=IF FIQ3 .EQ. 1 THEN CSO4 ELSE IF FIQ3 .EQ. 2 THEN
 FDUMS1 ELSE FDUMS2
4165 * NATURAL LOADINGS OF HYDROGEN,SULPHATES AND NITRATES (MEQ/M*M)
4175 APHEXN = .025119 * PRX
4185 CSO4N = (APHEXN - 1.299)/.503
4200 CNO3N = (1.4278 * CSO4N) + 16.3128
4205 * ANTHROPOGENIC LOADINGS OF NITRATES AND SULPHATES (MEQ/M*M)
4250 AMMX1 = (CNO3-CNO3N)+1.4278*(CSO4EX-CSO4)
4270 AMMX2=(CSO4-CSO4N)+(CSO4EX-CSO4)
4275 * TOTAL LOADING OF HYDROGEN (MEQ/M*M)
4280 APHEX=PHEX+.50342*(CSO4EX-CSO4)
4290 APICEX=APHEX-APHEXN
```

```
****************** - CHANGES TO DEPOSITION MODEL - *******************
```

(Recommendation numbers refer to recommendations in Section 2 of the text)

The natural and anthropogenic separartion of deposition levels can be eliminated (Recommendation 1).
The data files should contain monthly data for each of the four acid deposition ions (hydrogen, sulfate, nitrate and ammonium) for wet and dry deposition separately. New variables for nitrate and ammonium need to be added. (Recommendation 2).

For foliar (above ground) effects, the four deposition variables APHEX (hydrogen ion), CSO4EX (sulfate ion), CNO3EX (nitrate ion) and CNH4EX (ammonium ion) should be calculated as the sum of wet deposition levels for active growing months (May to October). (Recommendation 3.)

For soil effects, the four deposition variables APHEXA, CSO4EXS, CNO3EXS, and CBH4EXS should be calculated as the sum of wet and dry deposition levels for all months of the year. A user-specified parameter should be introduced which prorates annual deposition; the default should be set to 65% (Recommendations 3 and 5).

A user-specific parameter should be introduced to allow above-ground hydrogen ion deposition (APHEX) to differ from soil deposition (APHEXS). The default should equate APHEX and APHEXS. (Recommendation 4.)

The user should not input deposition levels which lie outside the range 3.5 < PH < 5.5 (Recommendation 7). This recommendation does not require changes to the code.

```
**********************************************************************

5000 *
5005 * FOLIAR MODULE
5010 *
```

```
5012 APHEX1=-LOG10((APHEX/(PRX/100))*XPOWERY(10,-6))
5015 *
5020 * CHANGE IN AGR. YIELD (ADY)
5025 *
5030 FU1=UNIRAND(.9,1.1)
5050 ADYS1=INTERPOLATION ON (APHEX1,1.5,0,3,1.32*FU1,3.5,1.32*FU1,4,1.16*FU1,5.5
,1,10,1)
5055 ADYS2=INTERPOLATION ON (APHEX1,1.7,0,3,1,3.5,1.1*FU1,5.7,1,10,1)
5060 ADYS3=INTERPOLATION ON (APHEX1,1.3,0,2.3,0.90*FU1,3.2,1,10,1)
5065 ADYS4=ADYS3
5070 ADYS5=ADYS3
5075 ADYS6=INTERPOLATION ON (APHEX1,2.1,0,3.0,0.88*FU1,3.5,.98,4.2,1,10,1)
5080 ADYS7=ADYS3
5085 ADYS8=ADYS3
5090 ADYS9=ADYS3
5095 ADYS10=INTERPOLATION ON (APHEX1,1.4,0,2.5,.9*FU1,3,1.1*FU1.3.5,1.15*FU1,4,1
.08*FU1.5.5,1.10,1)
5100 ADYS11=ADYS1
5105 ADYS12=ADYS1
5110 ADYS13=ADYS1
5115 ADYS14=ADYS2
5120 ADYS15=ADYS6
5125 ADYS16=ADYS3
5130 ADYS17=ADYS2
5135 ADYS18=INTERPOLATION ON (APHEX1,2.4,0,3.5,.9*FU1,4.5,1,10,1)
5140 ADYS19=ADYS3
5145 ADYS20=ADYS18
5150 ADYS21=INTERPOLATION ON (APHEX1,1.9,0,3,.9*FU1,3.5,1.1*FU1,4,1.1*FU1,4.5,1,
10,1)
5155 ADYS22=ADYS18
5160 ADYS23=ADYS21
5165 ADYS24=ADYS6
5170 ADYS25=ADYS1
5175 ADYS26=ADYS1
5180 ADYS27=ADYS1
5185 ADYS28=ADYS18
5190 ADYS29=ADYS1
5195 ADYS30=ADYS1
5200 ADYS31=INTERPOLATION ON (APHEX1,1.8,0,3,.88*FU1,3.5,1.03*FU1,4.1.03*FU1,5,1
,10,1)
```

******** -CHANGES TO FOLIAR RESPONSE MODEL (Above Ground) - **********

All crop types will have the same basic dose response function. These functions are in Exhibit 4.5 of the recommendations report, (Recommendation 1).

The user should be able to chose the type of probability distribution for the random variation, (e.g., uniform, normal or, triangular). A second choice should be whether the variation is correlated or uncorrelated amongst crop types, (Recommendation 2). If the choice is correlated then only one set of random numbers needs to be used. An example of the code for a uniform distribution and correlated deviations is as follows:

```
      FU3 = UNIRAND(.56,1.72)
      FU35 = UNIRAND(.55,1.72)
      FU4 = UNIRAND(.69,1.51)
      FU55 = UNIRAND(1.,1.1)
      ADYS1 = INTERPOLATION ON (APHEX1.1.8,0,3,FU3,3.5,FU35,
              4.,FU4,5.5,FU55)

      ADYS2 = ADYS1
              .
              .
              .
      ADYS36 = ADYS1
```

For the uncorrelated option each crop type would require a set of random generator calls and an interpolation statement.
The default in the model should be normal distribution with correlated variations (Recommendation 2).

```
**********************************************************************

5205 ADYS32=ADYS18
5210 ADYS33=ADYS18
5215 ADYS34=ADYS1
5220 ADYS35=ADYS6
5225 ADYS36=ADYS1
5499 *CALCULATION OF CROP YIELDS
5500 AYS1=AAS1*ANLTS1
5505 AYS2=AAS2*ANLTS2
5510 AYS3=AAS3*ANLTS3
5515 AYS4=AAS4*ANLTS4
5520 AYS5=AAS5*ANLTS5
5525 AYS6=AAS6*ANLTS6
5530 AYS7=AAS7*ANLTS7
5535 AYS8=AAS8*ANLTS8
5540 AYS9=AAS9*ANLTS9
5545 AYS10=AAS10*ANLTS10
5550 AYS11=AAS11*ANLTS11
5555 AYS12=AAS12*ANLTS12
5560 AYS13=AAS13*ANLTS13
5565 AYS14=AAS14*ANLTS14
5570 AYS15=AAS15*ANLTS15
5575 AYS16=AAS16*ANLTS16
5580 AYS17=AAS17*ANLTS17
5585 AYS18=AAS18*ANLTS18
5590 AYS19=AAS19*ANLTS19
5595 AYS20=AAS20*ANLTS20
5600 AYS21=AAS21*ANLTS21
5605 AYS22=AAS22*ANLTS22
5610 AYS23=AAS23*ANLTS23
5615 AYS24=AAS24*ANLTS24
5620 AYS25=AAS25*ANLTS25
5625 AYS26=AAS26*ANLTS26
5630 AYS27=AAS27*ANLTS27
5635 AYS28=AAS28*ANLTS28
5640 AYS29=AAS29*ANLTS29
5645 AYS30=AAS30*ANLTS30
5650 AYS31=AAS31*ANLTS31
5655 AYS32=AAS32*ANLTS32
5660 AYS33=AAS33*ANLTS33
```

```
5665 AYS34=AAS34*ANLTS34
5670 AYS35=AAS35*ANLTS35
5675 AYS36=AAS36*ANLTS36
5680 *CALCULATION OF FOLIAR DAMAGES
```

```
********** - CORRECT CHANGES IN REVENUE CALCULATIONS - **************
```

Note that the original code is wrong. The change in revenue is:

```
P * (Q' - Q)
```

ADYS1 is Q'/Q (line 5020) and AYS1 is Q (line 5300) in the code.

For example, line 5700 in the code equates change in revenue to:

```
AFCOST = 99 * AYSI * (1/ADYSI-1)
       = P * Q * ( 1/ Q/Q - 1)
       = P * Q / Q' - Q
       = P *(Q - Q)
```

The code should read

```
AFCOST1 = P * (Q'-Q)
        = 99 * Q * (Q'/Q  - 1)

AFCOST1 = 99 * AYSI * (ADYSI - 1)
```

This correstion should be made to lines 5700 through 5875 and 600 through 6185. The corection from the original model will change the sign of cost to positive benefit. Therefore the sign of ACOSTA. and ACOSTS04 must be changed as noted below.

```
*************** - ADD PRICE EFFECTS - *****************************
```

With price effects (Recommendation 6) it should be:

```
AFCOST1 = 99*AYS1*((ADYS1-1)+0.5*(ADYS1 - 1)*(ADYS1-1)/ELAST1)
```

Where ELASTn is the elasticity estimate for either fresh fruit or vegetables or cereals from section 4.5.2 in the text. Where elasticity estimates are not available (e.g., for tobacco), or prices are controlled by institutionally or by marketing boards, price effects should be set to zero. Price effects should be activated by the user by specifying an elasticity; i.e., the default should set price effects to zero. (Recommendation 10).

```
*******************************************************************

     UPDATE PRICE DATA (SECTION 4.5)

********************************************************************

     ADD MAPLE SUGAR PRICE DATA (Recommendation 3 and Section 4.5)

*******************************************************************

5700 AFCOSTS1=99*AYS1*(1/ADYS1-1)
5705 AFCOSTS2=.13*AYS2*(1/ADYS2-1)
```

```
5710 AFCOSTS3=16.5*AYS3*(1/ADYS3-1)
5715 AFCOSTS4=0.18*AYS4*(1/ADYS4-1)
5720 AFCOSTS5=3.87*AYS5*(1/ADYS5-1)
5725 AFCOSTS6=2.46*AYS6*(1/ADYS6-1)
5730 AFCOSTS7=2.45*AYS7*(1/ADYS7-1)
5735 AFCOSTS8=2.14*AYS8*(1/ADYS8-1)
5740 AFCOSTS9=44.8*AYS9*(1/ADYS9-1)
5745 AFCOSTS10=0.11*AYS10*(1/ADYS10-1)
5750 AFCOSTS11=154*AYS11*(1/ADYS11-1)
5755 AFCOSTS12=258*AYS12*(1/ADYS12-1)
5760 AFCOSTS13=1470*AYS13*(1/ADYS13-1)
5765 AFCOSTS14=8.72*AYS14*(1/ADYS14-1)
5770 AFCOSTS15=1.36*AYS15*(1/ADYS15-1)
5775 AFCOSTS16=4.0*AYS16*(1/ADYS16-1)
5780 AFCOSTS17=23.81*AYS17*(1/ADYS17-1)
5785 AFCOSTS18=0.82*AYS18*(1/ADYS18-1)
5790 AFCOSTS19=2.9*AYS19*(1/ADYS19-1)
5795 AFCOSTS20=0.05*AYS20*(1/ADYS20-1)
5800 AFCOSTS21=0.07*AYS21*(1/ADYS21-1)
5805 AFCOSTS22=0.06*AYS22*(1/ADYS22-1)
5810 AFCOSTS23=0.14*AYS23*(1/ADYS23-1)
5815 AFCOSTS24=0.08*AYS24*(1/ADYS24-1)
5820 AFCOSTS25=250*AYS25*(1/ADYS25-1)
5825 AFCOSTS26=0.09*AYS26*(1/ADYS26-1)
5830 AFCOSTS27=338*AYS27*(1/ADYS27-1)
5835 AFCOSTS28=0.15*AYS28*(1/ADYS28-1)
5840 AFCOSTS29=160*AYS29*(1/ADYS29-1)
5845 AFCOSTS30=0.15*AYS30*(1/ADYS30-1)
5850 AFCOSTS31=0.08*AYS31*(1/ADYS31-1)
5855 AFCOSTS32=0.22*AYS32*(1/ADYS32-1)
5860 AFCOSTS33=0.06*AYS33*(1/ADYS33-1)
5865 AFCOSTS34=567*AYS34*(1/ADYS34-1)
5870 AFCOSTS35=0.2*AYS35*(1/ADYS35-1)
5875 AFCOSTS36=0.05*AYS36*(1/ADYS36-1)
5900 AFCOSTSUM=SUM(AFCOSTS1 THRU AFCOSTS36)
6000 ALOSS1=AYS1*(1/ADYS1-1)
6005 ALOSS2=AYS2*(1/ADYS2-1)
6010ALOSS3=AYS3*(1/ADYS3-1)
6015ALOSS4=AYS4*(1/ADYS4-1)
6020ALOSS5=AYS5*(1/ADYS5-1)
6025ALOSS6=AYS6*(1/ADYS6-1)
6030ALOSS7=AYS7*(1/ADYS7-1)
6035ALOSS8=AYS8*(1/ADYS8-1)
6040ALOSS9=AYS9*(1/ADYS9-1)
6045ALOSS10=AYS10*(1/ADYS10-1)
6050ALOSS11=AYS11*(1/ADYS11-1)
6055ALOSS12=AYS12*(1/ADYS12-1)
6060ALOSS13=AYS13*(1/ADYS13-1)
6065ALOSS14=AYS14*(1/ADYS14-1)
6070ALOSS15=AYS15*(1/ADYS15-1)
6085ALOSS16=AYS16*(1/ADYS16-1)
6090ALOSS17=AYS17*(1/ADYS17-1)
6095ALOSS18=AYS18*(1/ADYS18-1)
6100ALOSS19=AYS19*(1/ADYS19-1)
6105ALOSS20=AYS20*(1/ADYS20-1)
6110ALOSS21=AYS21*(1/ADYS21-1)
6115ALOSS22=AYS22*(1/ADYS22-1)
6120ALOSS23=AYS23*(1/ADYS23-1)
6125ALOSS24=AYS24*(1/ADYS24-1)
6130ALOSS25=AYS25*(1/ADYS25-1)
```

```
6135ALOSS26=AYS26*(1/ADYS26-1)
6140ALOSS27=AYS27*(1/ADYS27-1)
6145ALOSS28=AYS28*(1/ADYS28-1)
6150ALOSS29=AYS29*(1/ADYS29-1)
6155ALOSS30=AYS30*(1/ADYS30-1)
6160ALOSS31=AYS31*(1/ADYS31-1)
6165ALOSS32=AYS32*(1/ADYS32-1)
6170ALOSS33=AYS33*(1/ADYS33-1)
6175ALOSS34=AYS34*(1/ADYS34-1)
6180ALOSS35=AYS35*(1/ADYS35-1)
6185ALOSS36=AYS36*(1/ADYS36-1)
7000 *
7005 * AGRICULTURE SOILS MODULE
7010 *
7015 *
7020 * HYDROGEN
7025 *
7045 ADMEQH=ATPA*AHICEX*4046.95

******************* - CHANGES TO THE SOILS MODEL - ********************

To determine liming requirements calculate variable AHICEX as a
sum of APHEXS (hydrogen ion) and additional sulfate acidification
over and above 20kg/hectare (Recommendation 4 and 5).
The new calculations for liming costs should be:

     AR = IF ABASE .LE. .2 THEN 0 ELSE IF ABASE .GE. .8 THEN 1 ELSE
          .026 * ABASE - .000164 * ABASE * ABASE - .078

     AHICEX = APHEXS + 2 * (.7 * .3 - AR) * CSO4EXS

Change sign of ACOSTCA to be consistent with yield and other cost
effects.

*************************************************************************

     UPDATE COSTS (PRICES) OF LIME (Recommendation 8 and Section 4.5)

*************************************************************************

7055 ACOSTCA = 1525 * XPOWERY(10.-9) * ADMEQH
7065 *
7070 *
7075 * NITROGEN
7080 * NOTE : MUST CALCULATE NON-LEGUMINOUS AREA
7085 * FIRST : PROD'N/ACRE

************************************************************************

  UPDATE AGRICULTURAL YIELD PER HA. SEE SECTION 4.5

***************************************************************************

  REVISE GROWTH RATE DATA.

  The growth rates in lines 7101 through 7260 should be revised from
   output from the CANQIDE or RIM models (Recommenation 11).

***************************************************************************
```

```
 ADD MAPLE SUGAR DATA (Recommenation 3, Section 4.5)

**************************************************************************

 AAS1=12.64,PREVIOUS * 1.029 FOR 11 ,PREVIOUS * 1.0145
7102 AAS2=5800.PREVIOUS*1.01 FOR 11.PREVIOUS *1.005
7105 AAS3=13,PREVIOUS * 1 FOR 11 ,PREVIOUS * 1
7110 AAS4=800,PREVIOUS * 1 FOR 11 ,PREVIOUS * 1
7115 AAS5=89.PREVIOUS * 1.029 FOR 11 ,PREVIOUS * 1.0075
7120 AAS6=1400.PREVIOUS * 1.033 FOR 11 ,PREVIOUS * 1.0690
7125 AAS7=57.4.PREVIOUS * 1.009 FOR 11 ,PREVIOUS * 1.0005
7130 AAS8=51.4.PREVIOUS * .9973 FOR 11 ,PREVIOUS * 0.9986
7135 AAS9= 2.7,PREVIOUS * 1.038 FOR 11 ,PREVIOUS * 1.019
7140 AAS10=3387.PREVIOUS * .9931 FOR 11 ,PREVIOUS * .9965
7145 AAS11=9.53.PREVIOUS * 1.010 FOR 11 ,PREVIOUS * 1.0055
7150 AAS12=6.09.PREVIOUS * .9900 FOR 11 ,PREVIOUS * .9950
7155 AAS13=1.19.PREVIOUS * 1.022 FOR 11 ,PREVIOUS * 1.0115
7157 AAS14=31.4.PREVIOUS * 1.01 FOR 11,PREVIOUS * 1.005
7160 AAS15=2005.PREVIOUS * 1.000 FOR 11 ,PREVIOUS * 1.0003
7165 AAS16=49.4.PREVIOUS * 1.018 FOR 11 ,PREVIOUS * 1.0094
7167 AAS17=12.4.PREVIOUS * .992 FOR 11.PREVIOUS * .996
7170 AAS18=1561.PREVIOUS * .9847 FOR 11 .PREVIOUS * 0.9923
7175 AAS19=51.6.PREVIOUS * 1.004 FOR 11 .PREVIOUS * 1.0021
7180 AAS20=26500.PREVIOUS * .9390 FOR 11 ,PREVIOUS * 0.9700
7185 AAS21=35400.PREVIOUS * 1.029 FOR 11 ,PREVIOUS * 1.0145
7190 AAS22=58290.PREVIOUS * 1.007 FOR 11 ,PREVIOUS * 1.0038
7195 AAS23=19700,PREVIOUS * 1.032 FOR 11 ,PREVIOUS * 1.0161
7200 AAS24=73900.PREVIOUS * 1.020 FOR 11 ,PREVIOUS * 1.0104
7205 AAS25=6.73,PREVIOUS * 0.983 FOR 11 ,PREVIOUS * 0.9920
7210 AAS26=18800.PREVIOUS * 1.013 FOR 11 ,PREVIOUS * 1.007
7215 AAS27=9.31.PREVIOUS * 0.998 FOR 11 ,PREVIOUS * 0.9991
7220 AAS28=21600.PREVIOUS * 0.974 FOR 11 ,PREVIOUS * 0.9873
7225 AAS29=6.67.PREVIOUS * 1.062 FOR 11 ,PREVIOUS * 1.0311
7230 AAS30=11400.PREVIOUS * 1.003 FOR 11 ,PREVIOUS * 1.0018
7235 AAS31=20000.PREVIOUS * 1.016 FOR 11 ,PREVIOUS * 1.0080
7240 AAS32=9400,PREVIOUS * 1.030 FOR 11 ,PREVIOUS * 1.0160
7245 AAS33=37900.PREVIOUS * 1.029 FOR 11 ,PREVIOUS * 1.0149
7250 AAS34=6.3.PREVIOUS * 1.061 FOR 11 .PREVIOUS * 1.0309
7255 AAS35=7200.PREVIOUS * 0.983 FOR 11 .PREVIOUS * 0.9917
7260 AAS36=39800.PREVIOUS * 1.011 FOR 11 ,PREVIOUS * 1.0055
7270 *CALCULATION OF CROP ACREAGES
7300 ANLTS1=ATPAS1/12.64
7305 ANLTS3=ATPAS3/13
7310 ANLTS4=ATPAS4/800
7315 ANLTS5=ATPAS5/89
7320 ANLTS6=ATPAS6/1400
7325 ANLTS7=ATPAS7/57.4
7330 ANLTS8=ATPAS8/51.4
7335 ANLTS9=ATPAS9/2.7
7340 ANLTS10=ATPAS10/3387
7345 ANLTS11=ATPAS11/9.53
7350 ANLTS12=ATPAS12/6.09
7355 ANLTS13=ATPAS13/1.19
7360 ANLTS15=ATPAS15/2005
7365 ANLTS16=ATPAS16/49.4
7370 ANLTS18=ATPAS18/1561
7375 ANLTS19=ATPAS19/51.6
```

```
7380 ANLTS20=ATPAS20/26500
7385 ANLTS21=ATPAS21/35400
7390 ANLTS22=ATPAS22/58290
7395 ANLTS23=ATPAS23/19700
7400 ANLTS24=ATPAS24/73900
7405 ANLTS25=ATPAS25/6.73
7410 ANLTS26=ATPAS26/18800
7415 ANLTS27=ATPAS27/5.31
7420 ANLTS28=ATPAS28/21600
7425 ANLTS29=ATPAS29/6.67
7430 ANLTS30=ATPAS30/11400
7435 ANLTS31=ATPAS31/20000
7440 ANLTS32=ATPAS32/9400
7445 ANLTS33=ATPAS33/37900
7450 ANLTS34=ATPAS34/6.3
7455 ANLTS35=ATPAS35/7200
7460 ANLTS36=ATPAS36/39800
7465 ANLTS2=ATPAS2/5800
7470 ANLTS14=ATPAS14/32.4
7475 ANLTS17=ATPAS17/12.4
7480 ANLT=SUM(ANLTS1 THRU ANLTS36)
7490 ANLTA=SUM(ANLTS2 THRU ANLT)

****** - CHANGES TO THE NITROGEN FERTILIZER COMPONENT -*************

      To eliminate the separation of anthropogenic natural sources of
      deposition, set

      AMMX1 = CNO3EXS + CNH4EXS  (Recommendation 1 in Section 2)

******************************************************************

      As previously noted, remove negative sign in line 7510 for
      calculation of ACOSTNO3.

******************************************************************

7500 ADMGNO3=ANLT*AMMX1*4046.95

******************************************************************

      UPDATE NITROGEN FERTILIZATION COSTS (Recomendation 8 and Section
      4.5)

******************************************************************

7510 ACOSTNO3=-10225 *POWER(10.,-9)*ADMGNO3
7520 *
7525 *
7530 * SULFATES

***** - ONLY TAKE BENEFITS UP TO THE AMOUNT OF SULFUR APPLIED - *****
           (Recommendation 4).

     AMMX2 = IF CSO4EXS .GE. (20 Kg/Ha)  THEN (20 Kg/Ha) ELSE CSO4EXS
```

```
**********************************************************************

     As previously noted, remove negative sign in line 7530 for ACOSTS

**********************************************************************

7535 *
7540 ADMGSO4=ATFA*AMMX2*4046.95

**********************************************************************

     UPDATE SULFUR FERTILIZING COSTS/PRICES (Recommendation 8 and
     Section 4.5)

**********************************************************************

7550 ACOSTSO4=-15414*XPOWERY(10,-9)*ADMGSO4
7560 *
7600 ASCOSTSUM=ACOSTCA+ACOSTNO3+ACOSTSO4
7610 ATOTCOST=ASCOSTSUM+AFCOSTSUM
7620 *
7625 ANPVF1=NPVC(ASCOSTSUM. INT RATE,0)
7630 ANPVF2=ANPVF1-MATRIX(ANPVF1.3)
7700 ANPV1=NPVC(ATOTCOST. INT RATE, 0)
7750 ANPV2=ANPV1-MATRIX(ANPV1.3)
7800 ANTV=NTV(ATOTCOST. INT RATE, 0)
END OF MODEL
```

F.3 Human Systems

Recommendation numbers refer to recommendations in Section 5 of the text, unless otherwise specified.

****

```
5 * HUMAN SYSTEMS MODEL
10 COLUMNS 1979-2000
15 * DEPOSITION SCENARIOS
20 * FIRST: DEPOSITION OF SO4 FROM ANTHROPOGENIC SOURCES IN MEQ'S
25 FIQ3=&HOW DOES ACID DEPOSITION VARY OVER TIME?1=CONSTANT,2=PREVIOUS
   +FACTOR3 ,3=PREVIOUS*FACTOR3&
30 FACTX3=&FACTOR3(0 IF CONSTANT)&
35 FDUMS1=CSO4,PREVIOUS +FACTX3
40 FDUMS2=CSO4,PREVIOUS*FACTX3
45 CSO4EX=IF FIQ3 .EQ. 1 THEN CSO4 ELSE IF FIQ3 .EQ. 2 THEN FDUMS1 ELSE
   FDUMS2
50 *NATURAL LOADINGS OF HYDROGEN
55 APHEXN=.025119*PRX
60 CSO4N=(APHEXN-1.299)/.503
65 AMMX2=CSO4EX-CSO4N
70 *TOTAL LOADINS OF HYDROGEN
75 APHEX=PHEX+.50342*(CSO4EX-CSO4)
80 * ANTHROPOGENIC LOADINGS
```

****

***** Changes to Deposition Model ******

(Recommendation numbers refer to recommendation in Section 2 of the text.)

The natural and anthropogenic separation of deposition levels can be eliminated (Recommendation 1).

The data file should contain monthly data for each of two acid depositions ions (hydrogen and sulfate) for wet and dry deposition separately Recommendation 2).

To calculate effects, deposition should be calculated as the sum of wet and dry sulfate ion levels for all months of the year (Recommendation 3 and 5)

For the water supply component of the human systems model, an average annual water pH and percent change from the current pH should be calculated for wet deposition (Recommendation 6 and Recommendation 17 from Section 5).

****

```
85 AHICEX=APHEX
```

****

```
85 AHICEX=APHEX-APHEXN
90 PHEX=0
```

****

Modify sulphate - SO2 relationship. (Recommendation 2).
Original code calculates SO2 from AHICEX (hydrogen ions).

```
100 MGSO2=.1143*AHICEX
```

Replace AHICEX with a new variable for annual average wet and dry sulphate depositions. Query user for conversion factor of sulfate to SO2 (i.e., 1143 in line 100 should be changed to a user - specific variable). If desired a default value based on equivalent atomic weights (i.e., sulfate 96 grams; SO2 64 grams) can be input.

****

```
95 * SECOND: CONVERT MEQ'S OF ANTHROPOGENIC SO4 INTO MG'S OF SO2
100 MGSO2=.1143*AHICEX
105 * MATERIAL SPECIFIC DAMAGE ESTIMATES
110 * MODEL PARAMETERS
115 DISCOUNT RATE =&DISCOUNT RATE ((1.0)&
120 DR= DISCOUNT RATE
```

****

Update Ontario and regional population data for base year (ONTP and REGD, respectively) (Recommendation 14).

Input population growth rate. Calculate new ONTP and REGP each year. (Recommendation 11).

****

```
125 ONTP=8522460
130 REGP=DATA
```

****

For each material, make the following changes:

Update consumption data (Recommendation 10), by revising values for ON___ (cf., ONCX for zinc). If desired, convert consumption data into volume terms by dividing by the average price of each material.

Allow material at risk to grow at the population growth rate (Recommendation 11) by including a growth rate factor for consumption data. For zinc, the revision would be:

```
ONCX = 36.5 * ONTP / 8522460
```

where ONTP is the Ontario population in each year, as defined above.

Verify economic life and exposure factors (cf., ECLX and EXPX for zinc) as per Recommendation 12 and 13.

Add dry deposition effects by eliminating adjustment to interaction values Recommendation 3). The adjustment is eliminated by dividing all 1980 interaction values (cf., INVXI for zinc) by 0.40.

****

```
135 * CALCULATIONS FOR ZINC

140 ONCX=36.5
145 ECLX=36
150 EXPX=.47
155 INVX = UNIRAND(INVXL,INVXU)
160 INVXL=.5*INVX1
165 INVXU=2*INVX1
```

****

Replace interaction values for zinc (Recommendation 8) as follows:

```
Line 170  INVXI = (92.8 + 1.73) * POWERY(10,-4)
```

Modify line 180 appropriately:

```
Line 180  ALFX = ONCX * ECLX * EXPX * LFX * (92.8 + 1.73 *
MGSO2) * POWERY(10,-4) * (REGP/ONTP)
```

****

```
170 INVX1=1.71*XPOWERY(10,-4)
175 LFX=2.7
180 ALFX=ONCX*ECLX*EXPX*LFX*INVX*(REGP/ONTP)*MGSO2
185 DAMAGES TO ZINC=NPVC(ALFX,DR,0)
190 * CLACUALATIONS FOR CONCRETE
195 ONCCIB=342.9
200 ECLCIB=40
205 ECIBPCIB=.34
210 LFCIB=3.1
215 INVCIB=UNIRAND(INVCIBL,INVCIBU)
220 INVCIBL = .5*INVCIB1
225 INVCIBU = 2*INVCIB1
230 INVCIB1=3.2*XPOWERY(10,-5)
235 ALFCIB=ONCCIB*ECLCIB*ECIBPCIB*LFCIB*INVCIB*MGSO2*(REGP/ONTP)
240 DAMAGES TO CONCRETE=NPVC(ALFCIB,DR,0)
245 * CALCULATIONS FOR COPPER
250 ONCCOPPER=156.9
255 ECLCOPPER=22
260 ECOPPERPCOPPER=.34
265 LFCOPPER=2.8
270 INVCOPPER = UNIRAND(INVCOPPERL,INVCOPPERU)
275 INVCOPPERL= .5*INVCOPPER1
280 INVCOPPERU =2*INVCOPPER1
285 INVCOPPER1=1.58*XPOWERY(10,-5)
290 ALFCOPPER=ONCCOPPER*ECLCOPPER*ECOPPERPCOPPER*LFCOPPER*
    INVCOPPER*MGSO2*(REGP/ONTP)
295 DAMAGES TO  COPPER=NPVC(ALFCOPPER,DR,0)
300 * CALCULATIONS FOR ALUMINUM
```

```
305 ONCALUM=192.2
310 EALUMPALUM=.34
315 ECLALUM=16
320 LFALUM=2.4
325 INVALUM= UNIRAND(INVALUML,INVALUMU)
330 INVALUML = .5*INVALUM1
335 INVALUMU= 2*INVALUM1
340 INVALUM1=1.42*XPOWERY(10,-6)
345 ALFALUM=ONCALUM*ECLALUM*EALUMPALUM*LFALUM*INVALUM*MGSO2*(REGP/ONTP)
350 DAMAGES TO ALUMINUM=NPVC(ALFALUM,DR,0)
355 * CALCULATIONS FOR PAINT
360 ONCPAINT=93.7
365 ECLPAINT=4
370 EPAINTPPAINT=.47
375 LFPAINT=3.9
380 INVPAINT = UNIRAND(INVPAINTL,INVPAINTU)
385 INVPAINTL = .5*INVPAINT1
390 INVPAINTU = 2*INVPAINT1
395 INVPAINT1=.67*XPOWERY(10,-4)
400 ALFPAINT=ONCPAINT*ECLPAINT*EPAINTPPAINT*LFPAINT*INVPAINT*
MGSO2*(REGP/ONTP)
405 DAMAGES TO PAINT=NPVC(ALFPAINT,DR,0)
```

****

Create a set of calculations for steel (Recommendation 6).

Consumption, economic life and value added and exposure factor for steel should be included in new appropriately named variables (ie., ONCSTEEL). From Salmon (1970), the following values can be used:

Economic life	18 years
Value added factor (labour factor)	2.3
Exposure index	.02

The interaction values should be calculated using Recommendation 7.

Note: Units of MGSO2 are Kg./Ha. in 1980 model conversion to ug/sqm. is necessary.

****

Remove Nickel calculations (Recommendation 5).

****

```
410 * CALCULATIONS FOR NICKEL
415 ONCNICK=30.6
420 ECLNICK=14
425 LFNICK=2.7
430 ENICKPNICK=.34
435 INVNICK = UNIRAND(INVNICKL,INVNICKU)
440 INVNICKL=.5*INVNICK1
445 INVNICKU =2*INVNICK1
```

```
450 INVNICK1=8.02*XPOWERY(10,-5)
455 ALFNICK=ONCNICK*ECLNICK*ENICKPNICK*LFNICK*INVNICK*MGSO2*(REGP/ONTP)
460 DAMAGES TO NICKEL=NPVC(ALFNICK,DR,0)
```

* * *

DAMAGES TO NICKEL should be replaced by DAMAGES TO STEEL in line 465.

* * *

```
465 TOTAL DAMAGES =DAMAGES TO ZINC+DAMAGES TO CONCRETE+ALFCOPPER+
     DAMAGES TO ALUMINUM+DAMAGES TO PAINT+DAMAGES TO NICKEL
```

* * *

Add water supply systems (Recommendation 16-20 and Section 5.5)

Create a data file for each water treatment system, specifying:

- pH levels of raw (intake) water
- average flow
- location (region)
- relationship between chemical additions and pH levels

For each system, calculate:

- pH with acid deposition (Recommendation 17)
- the difference in intake water pH with and without acid deposition
- treatment of chemicals required to adjust pH (Recommendation 18).
- the cost of incremental chemical requirements using average price data

OPTIONAL:
Create a data file for each community/district without water treatment systems, specifying analogous data as for water treatment systems. Introduce a user-specified threshold pH level, below which adjustments are made. Calculate incremental chemical costs as outlined for water treatment systems.

* * *

END OF MODEL

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REFERENCES

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